





















06.73  
06C28  
194  
218708  
73

# STUDIES ON THE VARIATION, DISTRIBUTION, AND EVOLUTION OF THE GENUS PARTULA

## THE SPECIES INHABITING TAHITI

---

By HENRY EDWARD CRAMPTON, PH. D.

*Professor of Zoology, Barnard College, Columbia University  
Curator of Invertebrate Zoology, American Museum of Natural History*

---



THE CARNEGIE INSTITUTION OF WASHINGTON  
WASHINGTON, 1916





# STUDIES ON THE VARIATION, DISTRIBUTION, AND EVOLUTION OF THE GENUS PARTULA

## THE SPECIES INHABITING TAHITI

---

BY HENRY EDWARD CRAMPTON, PH. D.

*Professor of Zoology, Barnard College, Columbia University*  
*Curator of Invertebrate Zoology, American Museum of Natural History*

---



THE CARNEGIE INSTITUTION OF WASHINGTON  
WASHINGTON, 1916



CARNEGIE INSTITUTION OF WASHINGTON  
PUBLICATION No. 228

*Copies of this Book*  
were first issued  
JAN 20 1917

PRESS OF GIBSON BROTHERS  
WASHINGTON

## CONTENTS.

	PAGE.
INTRODUCTION: The problems, the research, and the general results.....	9
CHAPTER I. The general features of the Polynesian realm in relation to the distribution of the species of <i>Partula</i> .....	13
Outline of the situation.....	13
General geography of the region inhabited by <i>Partula</i> .....	4
Geographical and geological features of the Society Islands.....	5
Winds, tides, currents.....	17
Temperature, rainfall, and barometric pressure in relation to the intra-insular distribution of <i>Partula</i> .....	18
Botanical and zoological associates of <i>Partula</i> .....	23
The habits and special natural history of <i>Partula</i> .....	24
CHAPTER II. The collections from Tahiti and their investigation.....	27
The species of Tahiti.....	27
The geography and topography of Tahiti, and the areas of habitation..	31
The collection, treatment, and analysis of the material.....	35
CHAPTER III. <i>Partula hyalina</i> Broderip.....	39
General considerations.....	39
The numerical distribution of <i>Partula hyalina</i> in Tahiti and its significance.....	40
The shell of <i>Partula hyalina</i> and its variation: Tahiti.....	44
Interpretation of the facts.....	48
Fecundity.....	49
Fecundity and elimination.....	50
<i>Partula hyalina</i> from the Cook Islands.....	51
General discussion of the distribution of <i>Partula hyalina</i> .....	54
CHAPTER IV. <i>Partula clara</i> Pease.....	57
General considerations.....	57
Numerical distribution of <i>Partula clara</i> .....	58
The shell of <i>Partula clara</i> : its morphological and geographical variations.	59
General description.....	59
<i>Partula clara parva</i> var. nov., Punaruu to Papehue Valleys.....	62
“ “ <i>incrassa</i> var. nov., Aoua Valley.....	63
“ “ <i>minor</i> var. nov., Orofere to Tiamao Valleys.....	65
“ “ <i>angusta</i> var. nov., Tereehia Valley.....	66
“ “ <i>prima</i> var. nov., Maruia to Vaihiria Valleys.....	67
“ “ <i>marmorata</i> var. nov., Maara to Farapa Valleys.....	70
“ “ <i>prima</i> (?), Papenoo Valley.....	72
Fecundity.....	73
The evolutionary significance of the variation and distribution of <i>Partula clara</i> .....	74
Summary and discussion.....	74
CHAPTER V. <i>Partula filosa</i> Pfeiffer.....	81
General considerations.....	81
The shell of <i>Partula filosa</i> and its variation.....	83
Fecundity and heredity.....	85
Summary and conclusion.....	86

	PAGE
CHAPTER VI. <i>Partula nodosa</i> Pfeiffer.....	87
General considerations.....	87
The geographical distribution of <i>Partula nodosa</i> .....	88
The regional variation of the shell of <i>Partula nodosa</i> .....	90
<i>Partula nodosa composita</i> var. nov., Taapuna Valley.....	91
“ “ “ var. nov., Punaruu Valley.....	94
“ “ <i>læva</i> Pilsbry, Maruapoo Valley.....	96
“ “ <i>exigua</i> var. nov., Atehi Valley.....	100
“ “ <i>intermedia</i> var. nov., Papehue Valley.....	101
“ “ <i>intermedia</i> var. nov., Aoua Valley.....	103
“ “ <i>intermedia</i> var. nov., Orofere Valley.....	104
Summary and conclusions.....	105
CHAPTER VII. <i>Partula otaheitana</i> Bruguière.....	113
General considerations.....	113
<i>Partula otaheitana otaheitana</i> var nov., Fautaua Valley.....	119
General statement.....	119
Fautaua Valley and the area of collection.....	120
Description of the Fautaua shells.....	121
Comparison of sinistral and dextral shells.....	123
Comparison of the color classes.....	125
Fecundity.....	127
Heredity.....	128
Summary and conclusion.....	129
<i>Partula otaheitana amabilis</i> Pfeiffer.....	130
General statement.....	130
Hamuta Valley.....	131
Pirai Valley.....	138
Pohaitara Valley.....	142
Ururoa Valley.....	144
General summary.....	146
<i>Partula otaheitana rubescens</i> Reeve.....	149
General considerations.....	149
Tuauru and Ahonu Valleys.....	151
Papenoo Valley.....	153
Faarumai, Tiarei, and Mahaena Valleys.....	159
Paraura Valley.....	160
Papeiha Valley.....	161
Haavini Valley.....	163
Tautira Valley.....	164
Aiurua Valley.....	165
Oopu Valley.....	166
Apirimaue Valley.....	170
A Mendelian interpretation of the heredity of color.....	170
Summary.....	181
<i>Partula otaheitana affinis</i> Pease.....	185
General considerations.....	185
The northern series—Tuauru to Papenoo Valleys.....	189
<i>Partula otaheitana affinis erythræa</i> subvar. nov., Farapa Valley.....	195
The eastern series of <i>affinis</i> —Faarumai to Faone Valleys.....	198
The northern Taiarapu colonies—Tehoro and Haavini Valleys.....	206
The general Taiarapu series—Tautira to Haoma Valleys.....	208
The Papeari colonies—Oopu and Apirimaue Valleys.....	212
The Mendelian inheritance of the color-pattern.....	213
Summary and conclusion.....	216



## CHAPTER VII—Continued.

	PAGE.
<i>Partula otaheitana sinistrorsa</i> Pease.....	219
General description.....	219
The colonies of Taiarapu.....	222
The colonies of Tahiti nui, Apirimaue to Taharua Valleys.....	228
The Mendelian inheritance of the color-patterns.....	243
Summary and conclusion.....	246
<i>Partula otaheitana sinistralis</i> Pease.....	250
General considerations.....	250
Description of the colonies, Teohu to Vaipuarui Valleys.....	251
Summary and conclusion.....	266
<i>Partula otaheitana crassa</i> Pease.....	268
General considerations.....	268
Southern <i>crassa</i> series, Vaitupa to Orofere Valleys.....	269
<i>Partula otaheitana crassa occidentalis</i> subvar. nov., Aoua and Papeh hue Valleys.....	274
Northern <i>crassa</i> series, Atehi to Punaruu Valleys.....	279
<i>Partula otaheitana crassa aberrans</i> subvar. nov., Taapuna Valley. Summary and conclusion.....	282
Summary and conclusion.....	284
<i>Partula otaheitana lignaria</i> Pease.....	286
General considerations.....	286
The shells and their variation.....	288
Fecundity.....	291
Heredity.....	292
Summary and conclusion.....	295
General Summary.....	296
CHAPTER VIII. <i>Partula producta</i> Pease.....	301
CHAPTER IX. Résumé.....	305
LIST OF ILLUSTRATIONS.....	313-342

## ERRATA AND ADDENDA.

Page 9, first paragraph, line 4, read Férussac for Ferrussac.

14, caption of plate 2, opposite page 14, the word "upper" should be in parentheses.

18, caption of plate 4, opposite page 18, the word "vertical" in line 3 should be in parentheses.

23, line 18 from bottom read (Plates 7B and 8) instead of (figures 11 and 12).

34, line 17, read Taiarapu for Tiarapu.

39, line 16, read plate 20 for plate 16.

69, line 11 from bottom, read Vairaharaha for Vaiaharaha.

171, line 9 from bottom, read Ahonu for Ahoruu.

181, second paragraph, insert comma after "make-up."

303, read Table 253 for Table 252 both in the heading of the table and in the text figure reference.



---

---

STUDIES ON THE VARIATION,  
DISTRIBUTION, AND EVOLUTION OF THE  
GENUS PARTULA.

THE SPECIES INHABITING TAHITI.

---

---



## INTRODUCTION.

---

### THE PROBLEMS, THE RESEARCH, AND THE GENERAL RESULTS.

The present memoir is the first of a series which is designed to give the results of recent studies upon the problems of variation, geographical distribution, and evolution in the case of certain Polynesian lung-snails belonging to the genus *Partula* of Ferrussac. The genus is restricted to the islands of the Pacific Ocean, and its headquarters are in the Society Islands in the southeastern part of Polynesia, although several species occur in Melanesia and Micronesia, as well as in other groups of islands at greater or lesser distances from the headquarters of the genus. In the course of the investigations upon which the present account is based, the species and varieties of this genus were studied not only with regard to their individual characters but also in connection with their general biological conditions, their geographical and topographical locations, and their apparent control in certain respects by meteorological and other external influences. In general terms, therefore, the subject of study may be stated as the natural history of the genus *Partula*, including the present ecological and past evolutionary relations of the various species.

Four journeys of exploration have been made. During the hot and rainy season of 1906, six weeks of the months of February and March were devoted to a first study in the island of Tahiti, which is the largest and most accessible member of the Society Group. In 1907 more than seven weeks of the months of June and July were spent in further explorations in Tahiti and in its near neighbor, Moorea, during a season which is slightly cooler and drier. In the corresponding season of 1908 a third period of field-work extended over the greater part of June, all of July, and the larger part of August, and during this time an almost complete survey was made of the islands of the so-called Leeward division, namely, Raiatea, Tahaa, Huahine, and Borabora, of which the first-named is by far the most important of all the places inhabited by *Partula* as regards the number of its species. Finally, in 1909, a fourth journey, comprising seven months, began again with field-work in Tahiti, Moorea, and Raiatea, in order to complete the study of certain important areas of these islands, and it was subsequently extended so as to include the Cook, Tonga, Samoan, New Zealand, Fiji, and Hawaiian Islands. Some material was obtained and many important observations were made in the Cook or Hervey Group, while in Samoa a month devoted to exploration yielded fairly satisfactory results in Upolu, although further studies are necessary to complete the investigations in this group. In the Hawaiian Islands, through the courtesy and kindness of Director Brigham and Dr. C. M. Cooke, of the Bishop Museum, the famous collection of *Partulæ* made by Andrew Garrett was thoroughly studied; a few excursions were made for the study in the field of the classic *Achatinellidæ*, whose ecological and evolutionary relationships are of the utmost importance in connection

with my own studies, particularly because the phenomena of distribution are similar and because these snails are close relatives of the *Partulæ* of Polynesia. No snails were obtained in Tonga or Fiji, as the islands of these groups in which *Partulæ* are reported to occur are small and relatively inaccessible. In all of the places visited, however, the exploration and detailed study of each additional group, island, and island-region established results which by contrast or similarity brought into clearer relief many features of great importance which had been previously noted elsewhere.

The initial journey was made under the auspices of the American Museum of Natural History; those of 1907 and 1908 were under the auspices of the Carnegie Institution of Washington, as well as that of 1909, when the writer had become an officer of the American Museum. To the friends of scientific research and of the American Museum who made it possible for the work to be begun, to the President and Trustees of the American Museum, and to the President and Trustees of the Carnegie Institution of Washington, these memoirs are offered as a partial and inadequate acknowledgment of the writer's indebtedness for the several opportunities afforded him for carrying on the investigations herein and hereafter described.

Since 1899 the writer has been engaged in laboratory researches upon the problems of variation, correlation, and selection in the case of certain saturniid moths, the quantitative results remaining unpublished in the main on account of their bulk and laborious statistical analysis; but the qualitative results were of such a nature that it seemed desirable to supplement them by an investigation which would determine the rôle played by environment as a whole in the differentiation of species and varieties existing under entirely natural conditions. Directed by an interest in the general subject of molluscan distribution, and specifically by the brilliant and suggestive research of Mayer upon the *Partulæ* of Tahiti, as well as by Mayer's personal advice, the writer undertook the close and detailed study in the field of that genus of terrestrial pulmonates. It may be stated at this juncture that no region could possibly be more favorable than Polynesia for the study of the problems in question; the writer cordially indorses the opinion of Mayer that the volcanic and other islands of the South Seas offer a field that in almost every respect attains the ideal of the biologist—a fact that will receive due enlargement and emphasis beyond.

Three primary subdivisions of the investigation were made at the outset. The first was a study of the problem of isolation and environmental influences as "conditions" or "factors" of biological differentiation. These have been variously estimated in the writings of naturalists from Darwin, Wagner, Murray, Wallace, Gulick, and Romanes to Allen, Jordan, Ortmann, and others, who have dealt with various groups of animals, and who have accorded to the "environment" almost all degrees of efficiency from omnipotence to impotence. In pursuance of this purpose it was planned to collect the snails as extensively as possible from all the valleys of the islands, thus to extend the observations of Mayer in Tahiti, and to make a complete survey of the whole group for comparison with the earlier observations of Garrett, who of all systematists concerned with the fauna of Polynesia has given the fullest and most circumstantial account of the distribution in his time of Par-

tulæ and of other terrestrial mollusca. Secondly, it was deemed desirable to carry further the work begun by Mayer upon the inheritance of shell and color characteristics, which are so important for the determination of the continuity or discontinuity of related forms. The material collected for the first purpose fortunately serves the second as well, for the snails are viviparous and many of the adult characters under investigation may be determined with complete or substantial accuracy for the young carried in the brood-pouch for weeks after development is begun, contrary to the opinions of Hartmann and others who have not been familiar with freshly caught material. In the third place it was planned to bring back living specimens to see if they would serve for laboratory experiments upon the course of inheritance in pure and hybrid strains; although many hundreds of snails have been successfully transported from the islands to the laboratory, and have been maintained alive for several months, it long since became evident that the work in the other departments must take precedence and must be completed before satisfactory experiments upon heredity can be prosecuted with entire advantage.

During the four journeys, more than 80,000 adult and adolescent individuals were obtained from over 200 valleys of larger and smaller size, in the Society Islands alone; the additional number of young snails contained in the brood-chambers of the adult specimens has not yet been fully determined, but the general average of embryonic snails that are sufficiently developed to display definite characters has proved to be about two for each adult of the several thousand already studied; thus there is ample material for the solution of certain perplexing problems dealing with the heredity of the diagnostic peculiarities of species and varieties.

In view of the length of time necessary for the thorough analytical study of the wealth of material already collected, it seems inadvisable to defer the publication of results until the entire research may be completed. The present memoir deals with those species only which occur in Tahiti, the largest of the Society Islands, although it includes a discussion of the features of the Polynesian area as a whole. In the course of the whole investigation, certain definite conclusions of a general nature have been confirmed or newly established, and for the sake of perspective it is desirable to give them in preliminary outline at this juncture:

(1) The snails are far from uniform in their distribution; with only one exception each group of islands has its own characteristic species which occur nowhere else.

(2) The same correlation between geographical and specific discontinuity is displayed by the species of the different islands of one and the same group, for each member possesses distinct species not found in the others, although in a very few instances important exceptions occur which throw much light upon the processes of dispersal and migration as well as upon certain geological relations.

(3) The species of *Partula*, like the Achatinellidæ of the Hawaiian Islands, may vary from valley to valley of an island; one form sometimes extends over a wide range, while another may be restricted to a few valleys or even to one; less obvious differences are displayed by types which inhabit different parts of a single valley. Statistical results prove the essential difference of races belonging to a species that has been heretofore regarded as invariable, while in other cases close relationships

have been established for species previously considered as separate. The study of the relations between young snails and their parents is of the highest importance in establishing these facts.

(4) The abundant material, taken in connection with the results of Garrett, gives astonishingly clear evidence of a recent origin of some types, while it is possible also to determine their parentage and rate of dispersal, when this has occurred, as well as the fixity of the new characteristics.

(5) Mutation has been demonstrated in numerous instances, and in many species belonging to several islands, so that it can not be regarded as a unique process.

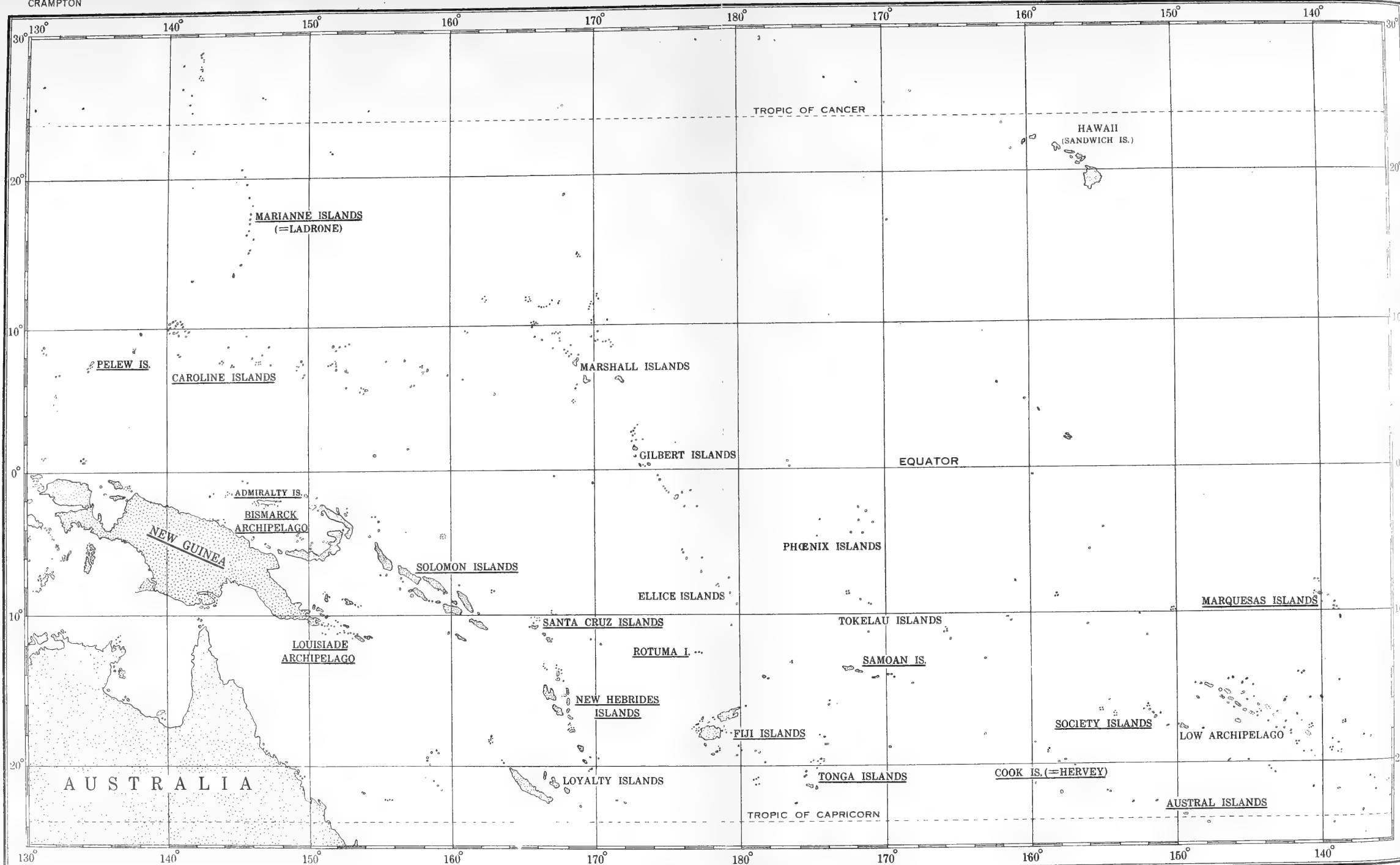
(6) The originative influence of the "environment" seems to be little or nothing. Isolation proves to be a "condition" and not a "factor" in differentiation of forms belonging to this genus.

(7) A result with a wider scientific bearing is established by the intercomparison of the snail populations of islands of the same group and of the species of different groups. The evidence tends to prove that the dominant geological process in South Pacific regions has been one of subsidence, which has progressively isolated various mountain ranges previously connected, so that they have become separate island-masses, which in their turn have been subsequently converted into the disconnected islands of the several groups. Here and there the reverse process of uplifting has caused many islands to rise above the surface of the ocean, but such uplifts are relatively rare and they seem to be the secondary results of the dominant process of subsidence. It is obvious that this complex subject is one that can be discussed with profit only after the detailed biological results have been presented in full.





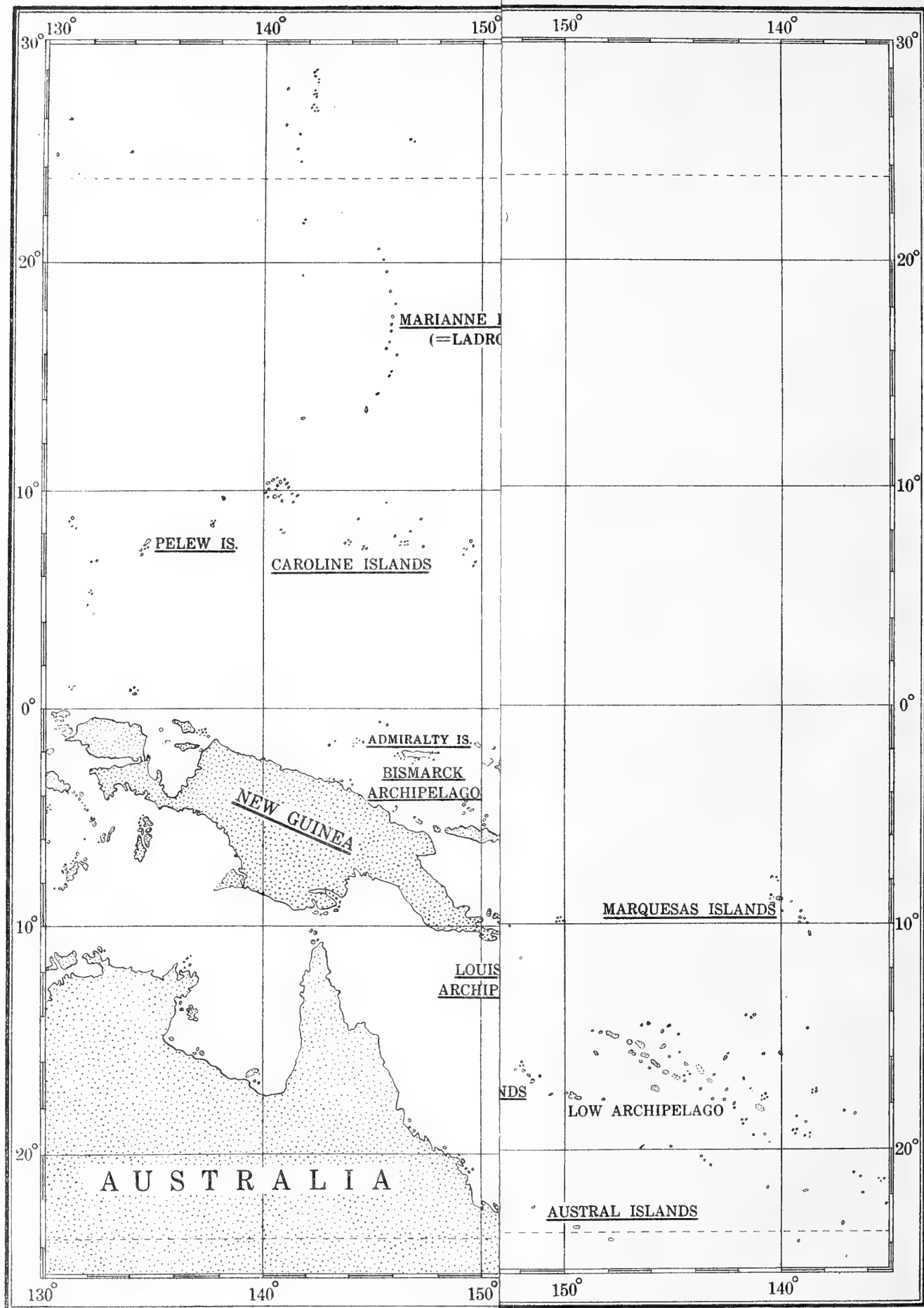
CRAMPTON



# CHART OF OCEANIA.

The groups of islands with underlined names are known to be inhabited by species of the genus *Partula*.





## CHAPTER I.

### THE GENERAL FEATURES OF THE POLYNESIAN REALM IN RELATION TO THE DISTRIBUTION OF THE SPECIES OF *PARTULA*.

#### OUTLINE OF THE SITUATION.

The present investigation is concerned with the characteristics displayed by certain Polynesian species of *Partula* and by their varieties, taking into account the environmental situations of all distinguishable forms. It is necessary, therefore, to consider the geography, geology, and climatology of the inhabited areas, as well as to make an analysis of the biological conditions that obtain in Polynesia. This descriptive review refers primarily to the southeastern portion of the whole region inhabited by the genus, where Tahiti and the rest of the Society Group are situated, because these islands are characteristic representatives of those that are to be found in Oceania, and because the writer's field studies have been conducted there more intensively than elsewhere. In addition, it appears that nearly one-half of all of the species are found in the Society Islands only, while, furthermore, these species belong, for the most part, to the most typical subgenus of the series, according to Pilsbry and others.

As a basis for the following description, it may be established at the outset that representatives of the genus *Partula* are found only on oceanic islands spread throughout a vast area of the south and west Pacific Ocean. They do not exist in the Hawaiian Group—the home of the related Achatinellidæ—although to the west they reach as high a latitude in the northern hemisphere. In the wide region of their occurrence they are distributed locally; that is, the genus is not represented in all groups of islands, nor do the species present in a group occur in all of its island elements. In general, it may be said that *Partulæ* are absent from the “low” islands, or coral atolls, and from most of the small “high” islands of volcanic and other nature; certain records attributing species to the Tuamotu and other atolls are undoubtedly erroneous. In a few instances, an island formed by the emergence of a coral mass above the sea may be inhabited by *Partulæ*, as in the Cook and Austral Groups.

The situation being what it is, it would be impossible to find a more ideal combination of circumstances for the investigation of the members constituting a definite biological group, and of their geographical distribution. The total area of occurrence is large, exceeding that of the United States; within this, the habitable bodies of land are separate islands, more or less distant from one another, associated in lesser or greater numbers in groups that lie relatively near or far apart. Hence the degrees of geographical relationship are marked with extraordinary distinctness, without any question of intermediate connections that intervene between comparable ecological regions of a single continent. Furthermore, it has long been known that within the confines of a solitary island the areas suitable for the

existence of *Partulæ*, are more or less isolated valleys, whose differing forms may be analyzed in correlation with their geographical and topographical proximity. In brief, then, the valleys and their diverse species constitute elements of a primary order, to be compared with one another; such elements taken together form an island-complex, which, as an element of a second order, may be contrasted with a similar complex of another island in the same association; uniting the several islands into a combination of a tertiary grade—the island group and its species—this may be investigated as a whole in relation to other combinations of the same status in different parts of the whole area. The circumstances are such, then, as to give an unusual interest and significance to the investigation of the genus *Partula* and its distribution, on the basis of a systematic and detailed analysis not ordinarily possible when dealing with similar problems of zoogeography.

#### GENERAL GEOGRAPHY OF THE REGION INHABITED BY *PARTULA*.

The line circumscribing that part of Oceania which includes the islands inhabited by *Partula* has the general form of a long oval or ellipse (plate 1). The long axis of this ellipse begins in the neighborhood of the Society Islands, about Lat. 20° S. and Long. 140° W., and it extends in a north-northwesterly direction to the Marianne or Ladrone Islands, about Lat. 17° N., Long. 135° E.—a distance of approximately 4,000 geographical miles. There is a single record of a species outside of this ellipse, in the case of *P. newcombiana* Hartman, which is assigned to Salibabu of the Talauer Group, near Mindanao (Lat. 2° 2' N., Long. 125° 40' E.). The easternmost inhabited group is the Marquesas, about Long. 138° W. The Ladrone Islands mark the limit in northern latitudes, while the Austral Islands, about 23° S., are the most extreme islands below the Equator to be inhabited.

TABLE 1.—General distribution of the species *Partula*.

Region.	Groups.	No. of species.	Total.
Polynesia.....	Society.....	44	63
	Marquesas.....	6	
	Austral, Cook.....	2	
	Samoan.....	8	
	Fiji, Rotuma, Tonga.....	3	
Melanesia.....	New Hebrides, Santa Cruz.....	17	37
	Solomon.....	11	
	New Ireland, New Britain, Admiralty.....	5	
	New Guinea, Louisiade.....	4	
Micronesia.....	Pelew.....	3	10
	Caroline.....	4	
	Marianne.....	3	
Malaysia.....	Talauer (Salibabu).....	1	1
			111

According to Pilsbry, the authentic species which are definitely assigned to the several groups and divisions of Oceania number at least 111, distributed as indicated in table 1. The salient facts are that Polynesia proper is the present headquarters of the genus, and that the Society Islands form the most congested part of this



The island of Moorea, drawn from charts and photographs. The greatest width, near the northern upper border, is approximately 10 geographical miles.





subsidiary area, inasmuch as two-fifths of all of the definitely located species reside in that group alone. To the northwest the numbers of species in the several groups decrease rapidly, although the suitable islands are in no wise diminished in number or area. The solitary species from Malaysia is remarkable, in view of the distance that separates its island from the nearest types, those of the Caroline Islands. Possibly further exploration will bring to light new forms that will fill in the existing wide gap.

#### GEOGRAPHICAL AND GEOLOGICAL FEATURES OF THE SOCIETY ISLANDS.

The group named the Society Islands by Captain Cook comprises fifteen elements of different extent and constitution. The location, geological nature, and other features of these islands are given in text-figure 1 and in table 2. Like that of the whole area, the outline of this group is an ellipse whose longer diameter trends from south-southeast to north-northwest. Within this outline the islands are grouped in the Windward and Leeward divisions, of which the former lies toward the southeast, the point from which the prevailing winds blow.

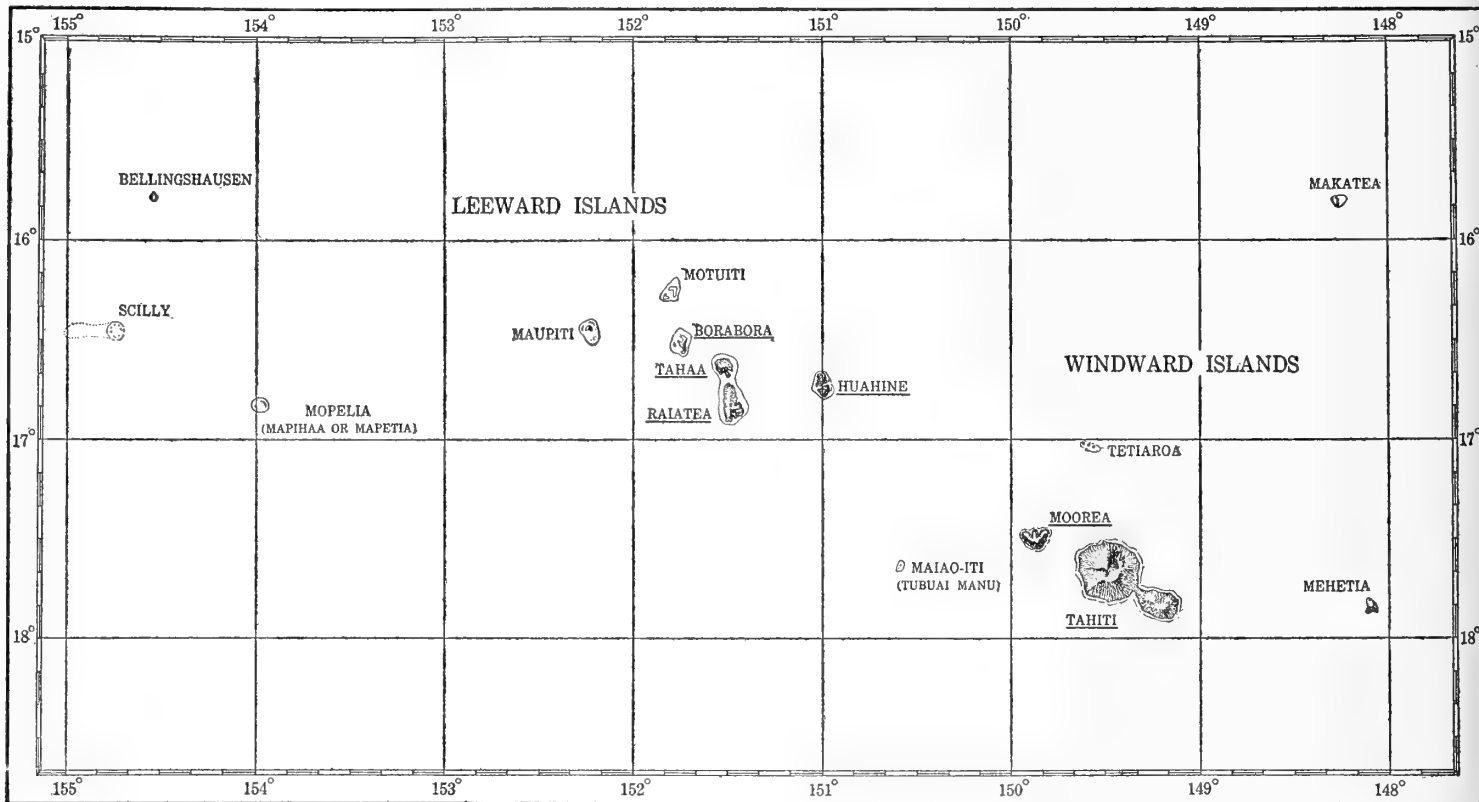
TABLE 2.—*General description of the Society Islands.*

Subgroup.	Island.	Character.	Approximate latitude, center.	Approximate longitude, center.	Approximate extent.	No. of species of <i>Partula</i> .
			° ' S.	° ' W.	sq. m.	
Windward...	Tahiti.....	Volcanic.....	17 39 S.	149 25 W.	350	8
	Moorea.....	Volcanic.....	17 32 S.	149 49 W.	40	4
	Mehetia.....	Volcanic.....	17 49 S.	148 7 W.	5	..
	Maiou-iti.....	Volcanic and coral...	17 38 S.	150 37 W.	3	..
	Tetiaroa.....	Atoll.....	17 3 S.	149 35 W.	2	..
	Makatea.....	Uplifted limestone...	15 48 S.	148 16 W.	5	..
Leeward....	Huahine.....	Volcanic.....	16 45 S.	150 59 W.	19	5
	Raiatea.....	Volcanic.....	16 50 S.	151 25 W.	60	21
	Tahaa.....	Volcanic.....	16 37 S.	151 28 W.	32	5
	Borabora.....	Volcanic and coral...	16 30 S.	151 44 W.	8	1
	Maupiti.....	Volcanic and coral...	16 27 S.	152 12 W.	11	..
	Motuaiti.....	Atoll.....	16 16 S.	151 49 W.	6	..
	Mopelia.....	Atoll.....	16 59 S.	153 58 W.	4	..
	Scilly.....	Atoll.....	16 27 S.	154 44 W.	4	..
	Bellingshausen..	Atoll.....	15 46 S.	154 32 W.	3	..

Tahiti (plate 9) is the largest member of the group, having an approximate area of 350 square miles. While its detailed structure will be described at a later point, its general features demand consideration here for the sake of their comparison with the characteristics of the other islands. It is a double volcanic mass whose greater and lesser parts—Tahiti nui and Tahiti iti or Taiaarapu—are connected by the low and narrow isthmus of Taravao. The larger part has almost the form of a pentagon whose longest diameter is about 25 miles; its circumference is about 75 miles. Taiaarapu is nearly 15 miles in length, with a circumference of 45 miles. Each part is an independent volcanic massif with a great primary crater basin, and with subsidiary vents outside of this. The greatest height of Tahiti nui is 7,500 feet, and that of Taiaarapu is a little less than 4,000 feet.

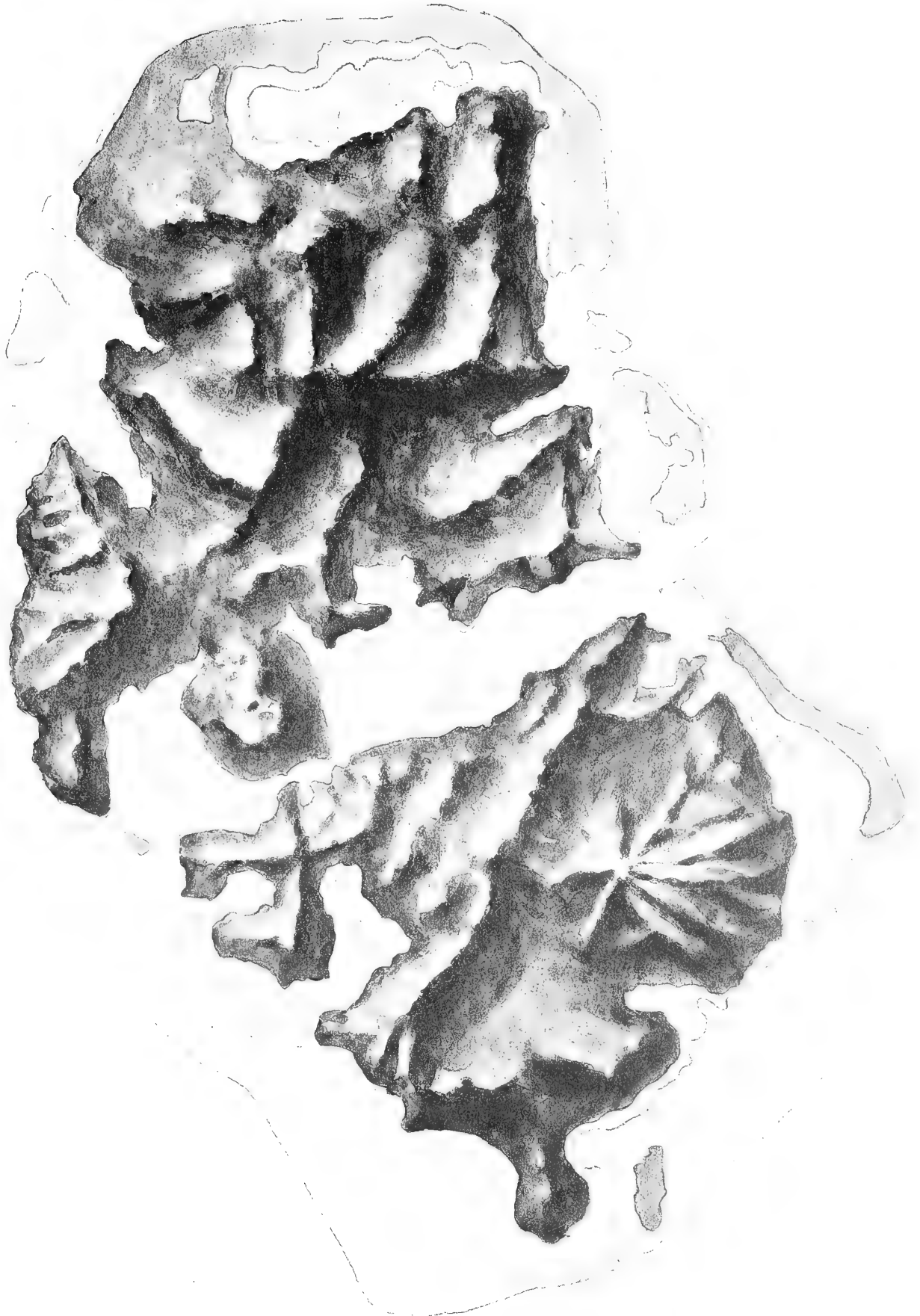
To the same class of "high" islands belong Moorea, Huahine, Raiatea and Tahaa, and Borabora, which, with Tahiti, constitute the series of six islands inhabited by species of the genus *Partula*. Moorea (plate 2), formerly called Eimeo,

is roughly triangular in outline and consists of a single volcanic mass; the crater of this has broken outward in such a way as to form two bays into which the sea has entered. Huahine (plate 3) is a double island, surrounded by a coral reef, whose two parts are separated by a narrow strait only a few score yards wide at its narrowest point and less than 0.5 mile broad at its greatest width. Raiatea and Tahaa (plate 4) are sister islands still encircled by a continuous line of reef; each of them is a single complex with one main crater only. Finally, Borabora is a sharply sculptured volcanic peak bordering a lagoon whose other boundaries are reefs for the most part.



TEXT-FIG. 1.—Chart of the Society Islands. The islands with underlined names are inhabited by species of the genus *Partula*.

In the aforesaid geographical features we find most favorable conditions for the inter-insular and intra-insular analysis of the snails, in so far as different degrees of isolation are displayed by comparable land-masses. The two parts of Tahiti are still connected, while those of Huahine are narrowly separated by water, giving a more advanced stage in the disconnection of peaks formerly united. Raiatea and Tahaa are 2 miles and more apart, but a single barrier-reef surrounds them, so that they show a stage beyond that of Huahine, albeit one that falls short of actual and complete disconnection. The final condition is displayed by Moorea in its relation to Tahiti as a whole. The inference is obvious that at a prior time the larger islands of this group were connected peaks, which have reached their present degrees of virtual, partial, or complete isolation by a process of subsidence. Certainly we can not adopt the alternative hypothesis of uplift for these islands, so as to interpret



The double island of Huahine, drawn from charts and photographs. The distance from the northern to the southern extremes of the two land-masses, taken together, (vertical distance) is about 8 geographical miles.



Huahine in terms of Raiatea-Tahaa, and Tahiti in terms of Huahine, for coral-limestone is lacking on the borders of the strait between the two parts of Huahine as it is on the Isthmus of Taravao connecting lesser and greater Tahiti. But in any case, the complete biological survey of the group is rendered unusually interesting in view of the well-marked degrees of isolation and proximity displayed by the several land-masses, with which the degrees of resemblance or diversity manifested by the *Partulæ* may be correlated.

As to the other islands of the group, little need be said, for they do not enter into the present investigation. Mehetia and Maupiti are small volcanic cones, with coral reefs. Most of the rest are coral atolls of circular or oval outline, while Makatea is an uplifted mass of coral limestone about 200 feet in height, exemplifying a kind of island that reaches its finest development in Vavau of the Tonga Group. Three contrasted geological types of islands, therefore, are represented in the Society Group; in the rest of Oceania the only additional type is the larger and older land-mass like that of Viti Levu of the Fiji Group. The islands that bear *Partulæ* are the larger ones of the "high" or volcanic type, separated by distances (table 3) that are to be taken into full account in discussing the biological relations of their species.

TABLE 3.—*Approximate distances between islands of the Society Group, in geographical miles.*

Island.	Moorea.	Huahine.	Raiatea.	Tahaa.	Borabora.
Tahiti.....	10	90	112	120	136
Moorea.....	..	70	92	100	116
Huahine.....	..	..	19	24	30
Raiatea.....	..	..	..	2.5	20
Tahaa.....	..	..	..	..	6

The topographical features of Tahiti, representative of those displayed by practically all of the "high" islands inhabited by *Partulæ*, are to be dealt with in detail in Chapter II; hence only a few points need be noted here. The central area of the main division, Tahiti nui, is occupied by a broad crater valley (Papenoo), surrounded by high ridges, save where the basin is continued outwards to the coast. On the outer slopes of the great crater boundaries, streams have eroded other valleys of larger and smaller size, among which at least four grades will be distinguished beyond. These radiating valleys are arranged with almost mathematical regularity, both in Tahiti nui (plates 5*a* and *b*) and in Taiarapu (plate 6*a*), which repeats the general features of the greater element. *Partulæ* do not occur on the ridges, but are restricted almost entirely to these radiating valley areas by a complex of factors which are climatological in their real nature, but whose combined effects are such as to establish the stated distributional relation to topographic features.

#### WINDS, TIDES, CURRENTS.

In discussing the factors that might exert an influence on the distribution of island organisms, the currents and winds must be recognized as possible agents of transportation and dispersal, even though, in the present case, their effects are negligible.

The prevailing winds in the Society Islands are the strong southeast trades that blow almost uninterruptedly for the greater part of the year. At times the wind may veer to the northeast, and to the south at the other extreme, but with lesser power when it does so. Hence the wind-currents pass from Tahiti toward Moorea and the leeward islands of the group. Likewise the main ocean-currents sweep from Tahiti and the southeast toward the northwest, although far beyond the Society Group the lines of flow straighten out toward Samoa in a due westerly direction. Conceivably, then, Tahitian species of *Partulæ* may have been carried passively to the shores of the other members of the Society Group, and even to more distant islands in other groups. Nevertheless the biological characters and ecological relations of these snails are such as to render such a view untenable.

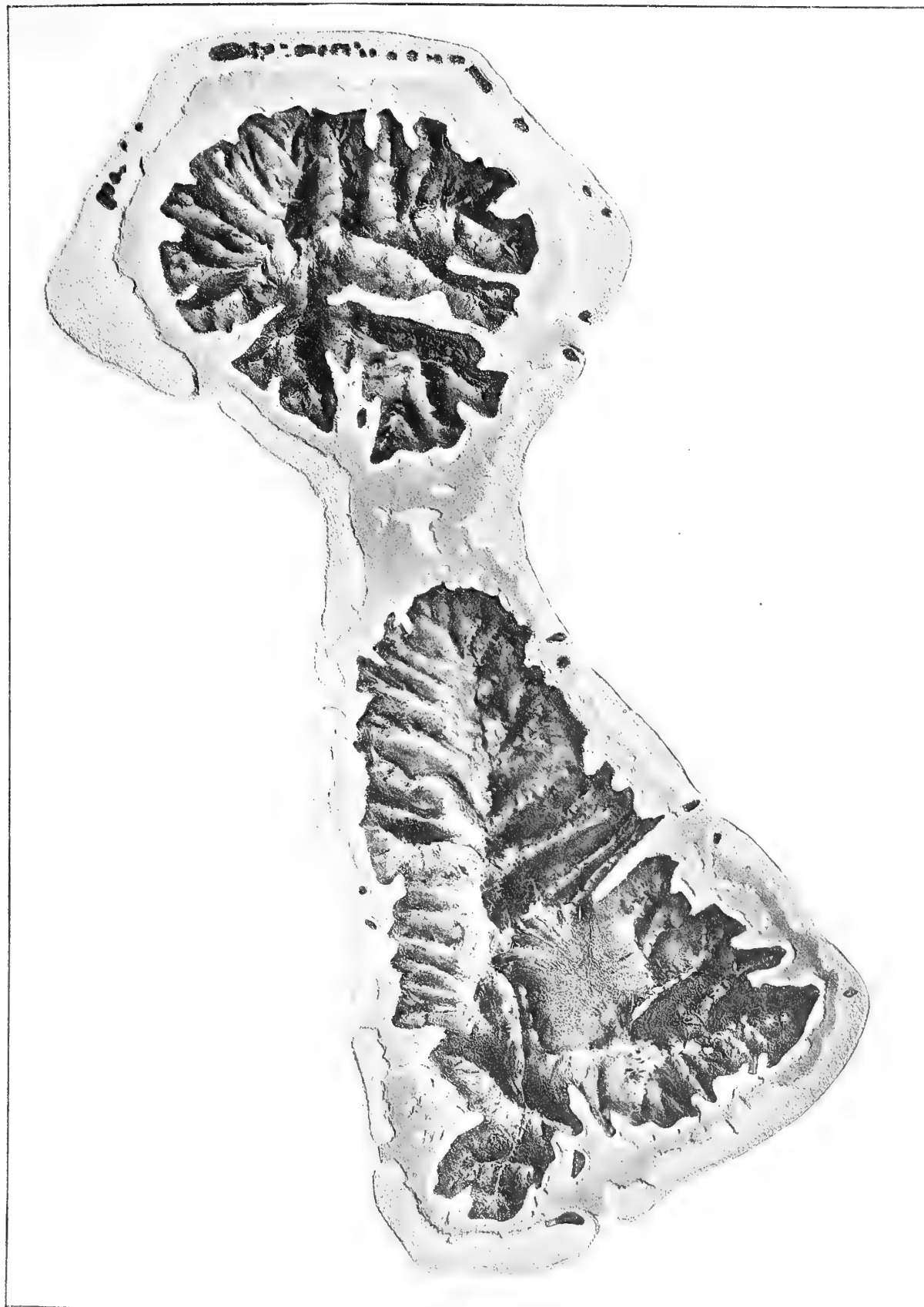
The tides of the Society Islands are almost unique in the world, by reason of the fact that high water occurs approximately at mid-day and mid-night throughout the year, owing to a peculiar combination of circumstances now well understood. Naturally the tides are of no effect on the distribution and transport of *Partulæ*, because the snails do not reach the shores in a living condition.

#### TEMPERATURE, RAINFALL, AND BAROMETRIC PRESSURE IN RELATION TO THE INTRA-INSULAR DISTRIBUTION OF PARTULÆ.

The three specified forms of environmental influence exert direct effects upon the *distribution* of *Partulæ*, although the question as to their values in relation to intrinsic characters is an entirely independent one. In general, the situation throughout the area inhabited by these snails is one of high temperature, much moisture, and low barometer; furthermore, these conditions are maintained with the greatest constancy throughout the year.

The "heat-equator" of the globe traverses the area occupied by the genus immediately north of the Society Islands. Tahiti is only a few hundred miles below this line, which here dips southward of the geographical equator to a distance of 10°. At the coast, the thermometer rarely rises during the day above 33° C. (93° F.), while at night, owing to the air-currents that flow downward from the high central peaks, the temperature drops, but rarely falls below 16° C. (60° F.) at any time. Variations in the ocean winds affect the temperature of the islands, always within narrow limits. The months from December to May are the hottest, but their extremes of temperature are not infrequently equaled during the alternative period.

As a basis for the present analysis of temperature conditions we have the official figures taken at Papeete, the principal town. Tables 4 and 5 give the fundamental data. But two facts must be borne in mind: first, that the station where observations are recorded is on the flat coastal plain; second, that it lies upon the northwest or leeward side of the island, sheltered by the high mountains from the full force of the trade-winds. Therefore, while the figures for Papeete may be taken as typical for the island in certain respects, in the nature of the case they can not adequately represent the temperatures met by the snails in the valleys and upon the higher ground near the central part of the island. Were it practicable, recording instruments should be placed at other points along the coast, in the valleys, and



The sister islands of Raiatea (lower) and Tahaa (upper)---a photograph of a topographical model constructed on the basis of charts, photographs, and observations. The length of Raiatea in a north and south vertical direction is  $11\frac{1}{2}$  geographical miles, while the similar diameter of Tahaa is a little less than  $6\frac{1}{2}$  geographical miles.





upon the mountains at different altitudes, so that simultaneous readings could be obtained, but it is difficult to do this without the expenditure of a disproportionate amount of time and energy. Certain data have been obtained, however, that show the general relation borne by other coastal points and by higher regions to the basic figures of Papeete.

TABLE 4.—*Temperature records at Papeete, Tahiti.*

	1901	1902	1903	1904	1905	Average for 5 years.	Average for 5 years.
	°C.	°C.	°C.	°C.	°C.	°C.	°F.
Mean temperature.....	25.9	26.2	26.9	25.3	25.3	25.9	78.6
Mean of maxima.....	31.5	33.3	32.7	30.5	30.6	31.7	89.0
Mean of minima.....	20.3	19.2	21.1	20.1	21.2	20.4	68.7
Mean oscillation.....	11.2	14.1	11.6	10.4	9.4	11.3	20.3
Absolute maximum.....	34.2	35.5	36.5	34.0	34.0	34.8	94.6
Absolute minimum.....	17.0	16.5	17.0	16.0	18.0	16.9	62.4
Absolute range.....	17.2	19.0	19.5	18.0	16.0	17.9	32.2

TABLE 5.—*Monthly variations of temperature at Papeete, Tahiti (degrees centigrade).*

	Mean of Maxima.						Mean of Minima.						Mean.					
	1901	1902	1903	1904	1905	Mean for 5 years.	1901	1902	1903	1904	1905	Mean for 5 years.	1901	1902	1903	1904	1905	Mean for 5 years.
January...	30.29	34.0	35.2	31.5	31.4	32.5	20.3	20.0	22.8	20.8	22.1	21.2	25.3	27.0	....	...	...	...
February..	31.35	34.0	35.3	32.2	31.7	32.9	21.7	21.0	22.2	20.9	22.1	21.6	26.5	27.5	...	...	...	...
March....	31.20	33.0	34.4	31.9	31.2	32.3	21.2	21.0	22.1	20.7	21.7	21.3	26.2	27.0	...	...	...	...
April.....	31.84	34.0	33.3	31.8	31.8	32.5	21.5	20.0	21.5	21.2	21.2	21.1	26.6	27.0	...	...	...	...
May.....	32.61	34.0	32.9	31.6	30.1	32.2	19.0	18.0	21.8	19.8	20.0	19.7	25.8	26.0	...	...	...	...
June.....	32.86	32.0	32.9	30.8	30.1	31.7	18.7	16.0	20.1	19.6	20.1	18.9	25.7	24.4	...	...	...	...
July.....	30.13	33.0	31.8	29.7	29.5	30.8	18.9	17.0	19.9	18.4	20.0	18.8	24.5	25.0	...	...	...	...
August....	31.20	33.0	30.5	28.3	29.1	30.4	19.3	17.0	20.1	18.8	19.7	19.0	25.2	25.0	...	...	...	...
September.	32.80	34.0	31.3	27.9	29.9	31.2	19.9	17.0	20.0	18.9	21.9	19.5	26.3	25.5	...	...	...	...
October...	31.20	34.0	31.7	29.7	30.1	31.3	21.6	19.0	20.4	19.8	22.0	20.5	26.4	26.5	...	...	...	...
November.	31.90	28.8	31.3	30.3	31.1	30.7	21.5	23.0	21.3	20.8	21.7	21.6	26.7	25.9	...	...	...	...
December.	30.90	35.5	31.6	30.8	31.6	32.1	19.6	28.0	21.4	21.4	22.2	22.5	25.2	28.7	...	...	...	...
Average.	31.52	33.3	32.7	30.5	30.6	31.7	20.3	19.2	21.1	20.1	21.2	20.4	25.9	26.2	26.9	25.3	25.3	25.9

Using maximum and minimum thermometers, it has been found that the diurnal variation for points on the west and south coasts is the same as for Papeete, and that as one passes from the leeward side to points less protected by the mountains the readings are slightly lower than at Papeete. For example, at Papara on the south coast, the maxima and minima were about 2° C. lower than for the same periods at Papeete. Seldom did the differences exceed 3° C. or fall below 1° C.

Of much more importance, as will appear in the later sections, were the differences observed in the case of higher levels. Nearly all those naturalists who have crossed the island unite in testifying to the cool or even cold night airs in the mountains. In the *Challenger* Reports, for example, the readings noted at the "head of Fautaua Valley" were as follows:

	°C.
Half hour before sunset.....	23.9
One hour later.....	20.2
Midnight.....	17.2
Daybreak.....	15.8
Half hour later.....	16.3

The temperature at the head of Punaruu Valley, at daybreak, was noted as 12.7° C., truly a low figure for the tropics.

Personal observations were made in the case of certain points along Fautaua Valley, from its mouth up to a point about halfway to the geometrical center of the island. Maximum and minimum readings at these points, as well as certain isolated observations, are given in table 6. The scale of a continuous-recording instrument placed at the highest station shows a diurnal curve that agrees with the coastal records as regards the times of highest and lowest points. Indeed, the comparable curves are almost exact counterparts in their characteristics, although the absolute values are about 6° or 7° C. lower for the higher station.

TABLE 6.—*Temperature records at different levels in Fautaua Valley, Tahiti.*

Station.	Distance from sea.	Approximate altitude.	July 7.		July 12.		July 7-12.	
			Time.	Temperature.	Time.	Temperature.	Maximum temperature.	Minimum temperature.
	<i>miles.</i>	<i>feet.</i>	<i>h. m.</i>	°C.	<i>h. m.</i>	°C.	°C.	°C.
Road at entrance.....	0.25	25	2 25 p. m.	28.5	.....	.....	.....	.....
Along footpath.....	0.75	50	2 35 p. m.	28.5	7 30 a. m.	20.5	29.4	20.0
Dead tree, snail area.....	3.5	425	3 32 p. m.	25.0	8 15 a. m.	18.3	27.2	18.3
Near rock, upper snail area	4.25	550	3 47 p. m.	25.0	8 33 a. m.	18.8	27.7	18.3
"Fort Faa-rahi".....	5.75	1,400	4 32 p. m.	23.0	9 45 a. m.	17.2	{ 24.4 on rock. 22.2 on ground.	{ 16.6 16.1

It is therefore evident that although the temperatures of various points along the shore are practically the same, the atmosphere becomes cooler at the rate of about 5° C. for every thousand feet of ascent towards the central peaks. The reason for the absence of *Partulæ* from the highest central areas of the island is found in the fact that lowered temperature inhibits their activity.

It must be noted, before passing on, that the relation between increase in altitude and decrease in temperature must necessarily be modified by other circumstances. When valleys trend north and south there will be in general a lower temperature for any given level than in a valley that runs east and west, into which the sun's rays enter during a larger part of the day. And furthermore, *cæteris paribus*, a valley with high and steep sides will be cooler than a shallow depression, or one whose sides slope gradually upwards.

Throughout Polynesia the rainfall is abundant, and humidity (like the temperature) is relatively high and constant. The factors are the great areas of ocean from which moisture is drawn, and the heavy trade-winds that carry this moisture to the land-masses, where, on the cooler mountain heights, clouds are formed and rain falls heavily. After about 9 a. m. every day, the clouds begin to mass upon the mountain peaks and cover a lesser or greater part of an island until late in the afternoon. Very rarely, and then only during the season of diminished rainfall, does the profile of the central mountains of Tahiti appear during the middle of the day.

Yet even in an island like Tahiti, situated in a region of great heat and humidity, the conditions of moisture vary in different parts of the land-mass, owing to



A. The town of Papeete and adjacent valleys. Fautaua Valley is on the right, and its main fork is marked by the summit of the Pic de Francaise (see Plate 7, B). Hamuta Valley is in the exact center, over the spire of the Cathedral. Pirai Valley runs below and parallel to the great ridge in the distance. Mt. Aorai is covered by clouds.



B. The alternating ridges and valleys looking toward Mt. Aorai from Mt. Tahara, at the extreme northern point of Tahiti near Point Venus.



qualifying factors. A section or valley located in the southern, southeastern, or eastern part will have a far greater rainfall than a valley on the leeward or north-western slopes of the main massif, on account of the direct sweep of the moisture-laden trade-winds against the southeastern areas. It is true that the clouds roll past the central peaks and that much rain falls in the upper part of a leeward valley whose middle and lower portions are relatively dry; and it is also true that when the wind veers to an unusual point of the compass, a region of much moisture may suddenly experience a period of drought. But the general statement stands, namely, that the windward sides are wetter than the leeward parts.

As a basis for an estimate of the actual amount of rain, we may employ the official records taken at Papeete; but these, like the figures for temperature, must not be regarded as representative for all parts of the island. The data of table 7 exhibit much variation for a given month during a succession of years, and marked differences between succeeding years as well; yet in general the months of less intense heat (May to September) have less rain than the alternative period. February is the wettest month, and this is a fact to be emphasized in view of the effect that is exerted by high humidity upon the activities of *Partulæ*.

TABLE 7.—*Statistics of rainfall at Papeete, Tahiti.*

	Rainfall (mm.).						Hours of rain.					
	1901	1902	1903	1904	1905	Average.	1901	1902	1903	1904	1905	Average.
January.....	561.6	69.6	121.0	275.4	153.9	236.30	22	19	10	16	12	15.8
February.....	578.3	1,028.9	206.1	159.1	188.5	432.18	22	22	16	13	9	16.4
March.....	219.8	106.0	203.1	163.6	197.9	178.08	12	13	11	13	8	11.4
April.....	114.7	93.2	328.4	102.4	0	127.74	16	7	13	6	0	8.4
May.....	72.7	0.5	320.0	98.3	71.0	112.50	9	1	16	6	7	7.8
June.....	73.6	83.4	26.9	31.5	111.7	65.42	9	7	4	4	10	6.8
July.....	160.2	52.6	283.9	82.4	12.0	118.22	6	6	9	7	3	6.2
August.....	187.0	116.0	135.0	41.9	11.6	98.30	11	7	12	5	1	7.2
September.....	133.7	110.0	80.2	54.7	0	75.72	11	11	11	6	0	7.8
October.....	538.7	198.4	49.1	54.7	83.0	184.78	13	6	8	7	4	7.6
November.....	120.2	100.5	273.9	66.4	103.9	132.98	14	7	12	6	7	9.2
December.....	505.5	119.9	404.5	188.1	75.9	258.78	18	16	18	13	2	13.4
Total {mm. ....	3,266.0	2,079.0	2,432.1	1,318.5	1,009.4	2,021.00	163	122	140	102	63	118
{inches. ....	130.64	83.16	97.28	52.74	40.37	80.84						

Humidity is high, as indicated by the figures of table 8, also based upon observations at Papeete. Not only is atmospheric moisture abundant, but its fluctuations in diurnal respects occur between narrow limits.

Realizing that Papeete lies on the protected leeward side of the island, and is subject to eddies of wind rather than to steady trades, it is clear that an estimate of rainfall elsewhere must give much increased figures. On the Hitiaa side, rain falls during at least three times as many hours as at Papeete, and hence the total precipitation would be estimated at about 250 inches a year. But taking all of the foregoing facts into account, it is clear that in the high central parts of Tahiti there must be a prodigious amount of rain. Practically every day of the year, from 10 a. m. to at least 3 p. m., the clouds are massed on the peaks and rain is falling somewhere. Assuming that this is true for 300 days, and for only one-quarter of

the clouded period for a given valley-head, the total number of hours of rain would be 1,500. At Papeete there is a deposition of 0.68 inch for each hour of rainfall, on the average (table 7); hence 1,020 inches would fall every year on the given inland area! From personal experiences in the interior, this enormous total does not seem too far beyond the actual amount; ten days' continuous rain has been witnessed, even near the coast on the windward side, while in Samoa on one occasion 4.5 measured inches of rain fell in 2.5 hours. In any case, the just conclusions from the available data are: (1) that the windward side of Tahiti is far wetter than the opposite part; (2) that the interior is more moist than the coast; (3) that large, deep valleys are more humid than small or shallow ones, which collect less water in their streams or which soon lose much of their moisture through evaporation.

TABLE 8.—*Statistics of humidity (in percentages) at Papeete, Tahiti.*

	1901	1902	1903	1904	1905
Absolute maximum.....	98	94	98	97	99
Absolute minimum.....	63	66	65	65	61
Average, 8 a. m.....	..	84.6	83.5	84.3	..
Average, 4 p. m.....	..	82.9	74.8	78.9	..

Snails of the genus *Partula* are somewhat definitely conditioned as to their distribution by the amount of moisture in the atmosphere. The drier coastal areas of the leeward side are devoid of them, and this is true of the peripheral parts of the valleys. On the windward side, however, the region of high humidity extends down toward the shores, almost reaching these in some places; hence the snails are to be found at far shorter distances from the sea.

Barometric pressure remains remarkably constant throughout the entire calendar day, being on the average (1903) 30.40 inches at 8 a. m. and 30.34 inches at 4 p. m., Papeete records. The pressure lessens rapidly and regularly as one leaves the coast in ascending the mountains and valleys. *Partulæ* are found as a rule only in the valleys at some distance from the coast, but their seeming relation in distribution to barometric influence is only indirect, through their real restriction by temperature and moisture conditions that are usually realized only at upper levels.

In brief, then, topographical and climatological conditions at Tahiti are such that two distinct regions are established, one being the peripheral coastal plain with relative lower rainfall and higher temperature, which is devoid of *Partulæ*; this encircles the second and contrasted area of excessive moisture, somewhat lower temperature, and much lower barometric pressure, which centers around the high mountain peaks that are protected from the sun's rays by the dense clouds. The latter region extends in all directions down the larger valleys towards the coast-line, to a distance that is determined by the extent of the daily cloud-cap, by the amount of moisture shed from the high ridges into the valley streams, and by the height and slope of the side-walls of the valleys. A valley that runs east and west will naturally be drier and hotter than one trending north and south; in those valleys whose walls rise precipitously, so as to shut out most of the sun's rays during the greater part of the day, the moist area may extend almost to the coastal plain; indeed, at some



A. The southwestern portions of Taiarapu, from the shore of Papeari District (photo. Harrison G. Smith).



B. Looking inland into Temarua Valley (center) and Papeiti Valley (at the right) from the open land near the coast. The thickets of guava and associated bushes in the foreground are characteristic of the dryer peripheral shelf and of the lower levels of the valleys.





points on the windward side of the island the coast may actually be reached. When the valley opens widely upon the alluvial plain the dry peripheral zone may extend centrally for many miles before grading insensibly into the moist area.

Near the shore-line the ridges are as dry and as hot as the coastal shelf itself; passing towards the central peaks more rain will be encountered, but this is so rapidly shed into the intervening valleys that the dry region penetrates far into the interior. Only in the highest parts do the ridges revert to the moist region. Therefore the two principal regions interdigitate with one another, for the outward radiations of the central high and wet regions continue into the low valley bottoms and alternate with the ridges that in an ecological sense are centripetal extensions of the low, dry, and hot coastal plain.

#### BOTANICAL AND ZOOLOGICAL ASSOCIATES OF PARTULÆ.

The limits of the two climatological regions distinguished in the foregoing section are further emphasized by the diverse botanical associations existing in them. As Partulæ are restricted to a portion of the inner moist area, the plant types of this are of special interest.

The dry coastal shelf and the lower parts of the large valleys are grassy plains bearing groves of coconut palms, bread-fruit (*Artocarpus*), and various forms of tropical Leguminosæ, such as *Mimosa* and *Erythrina* ("flamboyant"). The orange, lemon, and guava (imported in 1808) also thrive in such places (plate 6*b*), as well as other exotics like the mango and the lantana—a bush that has spread with great rapidity, so as to be a serious hindrance to island agriculture. Upon the ridges between the outward parts of the valleys (plate 7*a*), trees and low shrubs are practically lacking, so that only grasses and a few suitable species of ferns form the whole plant association.

Penetrating the valley, one usually finds Partulæ only where the guava thickets give place to a mixed forest of large trees (figs. 11 and 12), beneath whose shade the smaller succulent shrubs and herbs find a sufficiently moist habitat. Among the trees of forest growth are the tamanu (*Callophyllum*), hutu (*Barringtonia*), miro (*Thespesia*), and mape (*Inocarpus*). Sometimes Partulæ are found upon the trunks of such trees and upon their saplings and seedlings. More frequently, however, they appear on the under side of leaves of the banana and wild plantain (fei, *Mussa*), caladium ('ape, *Colocasia*), turmeric (*Curcumar*ia), wild ginger, and *Dracæna* (ti). Various species of *Pandanus* also grow in the interior, sometimes in a well-marked zone along the valley-wall at the edge of the true forest and just below the treeless grassy ridges. The *Pandanus* belt marks the lateral boundaries of the area inhabited by Partulæ; above this the drier open area acts as a barrier to migration. While the suitable nurse-plants extend far toward the center of the island, where dense groves of plantain and other succulent plants are to be found (plate 8), the snails are prevented by the lowered temperature of high altitudes from reaching the central area across which they could otherwise make their way to another valley. Furthermore, the high, precipitous cliffs so frequently encountered at the head of a valley afford no foothold for the thick plant-growth that is necessary for the snails' habitation.

While all of the inhabited valleys support the same kind of flora, whose elements are arranged in the same zonal manner, yet the relative abundance of the several representatives varies strikingly. One may contain an abundance of caladium and plantains, such as Fautaua, while a neighbor like Tipaerui will have a far greater proportion of turmeric, ginger, and *Dracæna*; yet it is impossible to discover any correlation between the dominance of a nurse-plant and the characters displayed by the snails of a given valley; in valleys with the same prevalent type of plant the snails may be identical or dissimilar, while in valleys that display different botanical conditions the snails may also be the same or unlike one another.

Passing now to the general zoological conditions, the most striking feature is the paucity of animal life in the valleys, aside from insects and the snails themselves. No invertebrates have been found to be enemies of the Partulæ, although there may be minute or microscopic species that are parasitic upon them. Lizards are abundant everywhere, but usually insectivorous, and would scarcely prey upon a snail provided with a large, thick shell. Birds are surprisingly few in species and in numbers and they are either small insectivorous forms or larger fruit-eating species. The introduced rat is the only animal that may directly concern the Partulæ in a slight degree. In the lower areas of the large valleys shells have been found that had certainly been gnawed by rats; they belonged to all of the species and color varieties that existed in such valleys. The snails remain during the day on smaller shrubs and plants upon which rats can not climb, and as the latter are not abundant save in the neighborhood of the coast, where Partulæ are few in numbers, we would scarcely regard these mammals as having an important influence upon the characteristics or even the abundance of land-snails of any species.

#### THE HABITS AND SPECIAL NATURAL HISTORY OF PARTULÆ.

Hitherto we have been concerned with the environmental conditions that affect the distribution of Partulæ by limiting their sphere of habitation to restricted valley areas in islands like Tahiti. We may now turn to the special consideration of the habits of the snails and of their reactions to external energies, as these are observed *within* the inhabited regions. Besides the observations upon the animals in the field, much has been ascertained through the study of snails in captivity in the laboratory, as regards the relation of Partulæ to gravity, heat, moisture, and light.

Three groups of species can be distinguished on the basis of reactions to gravity. *P. producta* in Tahiti is a type of the forms that live always on the ground, lurking under stones, dead trees, and dead leaves, such as those of the caladium and plantain. In a species like *P. fusca* of Raiatea the animals are not always confined to the ground, but will climb upwards to a height of 3 or 4 feet to rest under the leaf-sheaths of a plantain, or more infrequently on the external surface of a trunk itself. The second group comprises the greater number of species in Tahiti, in the Society Islands and elsewhere, whose representatives are arboreal during the daytime, remaining sealed up on the under sides of leaves less than 10 to 15 feet from the ground; at night, however, they resume activity and crawl to the earth to feed upon

A



A. The mouth of Faaripoo Valley, in the northern sector of Tahiti nui, showing the character of the country in the dryer regions.

B



B. Pic de Francaise and vegetation, at the main fork of Fautaua Valley, four geographical miles from the coast. (Photo. Bopp du Pont).



decaying vegetation. The third group is typified by *P. attenuata* of Tahiti and Raiatea; the snails of that species remain high up on the leaves of trees, where apparently they obtain their food from the twigs, branches, and limbs. This third group is characterized by relatively thin, translucent, horny shells, quite different from the heavier calcareous structures formed by the ground and arboreal types. In brief, the snails of the first group are positively geotactic almost without variation, those of the second are positively geotactic at night and negative in their reaction during the day, while the species of the third group are negatively geotactic at all times.

As regards phototropism and photopathy, the fundamental fact is that the snails remain quietly at rest or sealed up by a mucous secretion during bright daylight. The ground snails seek the darkness underneath stones and other objects. Those that are arboreal come to rest *underneath* leafy surfaces, and are thus negatively photopathic. Yet it is difficult to distinguish between the reaction to increased or reduced light-influence and the reaction to varying degrees of humidity. Under normal conditions of the latter, *Partulæ* resume activity at night and become quiet in bright light, in practically 95 per cent of the cases as observed in the laboratory, and in experiments in the field where snails were placed on suitable plants at the coast for the determination of this point. But if the atmosphere is very dry, they are apt to remain sealed up all night, while, on the other hand, if the sky becomes clouded and light is reduced, they will crawl about even in the daytime. When rain falls and humidity increases greatly, they move about with celerity, crawl to the ground, and resume feeding. It is interesting to note that partly grown or adolescent snails are much quicker than the adults in their reactions to reduced light and to increased degrees of moisture.

An additional factor of the resultant—quiescence or activity—is the temperature. In the field and in the laboratory the snails are brought to rest by a reduction of this to 60° F. or 55° F. Naturally, if it is darker and more humid, a still lower figure must be reached in order to bring the snail to rest; increase of temperature beyond the average by itself does not affect the snails, but greater heat is usually experienced during the daylight, when the latter acts as an inhibiting factor.

While the mating habits of snails can rarely be observed, owing to their nocturnal life, several pairs have been found *in coitu* in the daytime, when heavy rains were falling. Although the animals are hermaphrodite, it is certain that fertilization is not mutual; one acts as the male and the other as a female. In studying the conditions of preserved snails in the course of analyzing the collection, it appears that the male generative organs are larger in those individuals that bear no eggs or embryonic young; hence it seems probable that the hermaphrodite animals are alternately male and female in their virtual constitution and activities. Yet the number of gravid snails is almost always more than half of the total number taken from one valley, so that an acting male must fertilize a number of other snails, or else an impregnated individual may function as a male during the development of its embryonic contents.

The character of the food of *Partulæ* is a matter of considerable interest, in view of the theoretical possibility that differences in the vegetation of separated valleys might be adduced to account for the diverse characteristics of the snails in such different localities. When the facts are examined, however, this possibility is ruled out. Confining our attention to the low arboreal species, and disregarding those of the ground and of the highest tree-tops, we have several independent series of data that justify the statement given. In the first place, it is clear that the snails do not feed on the living tissue of the plants upon which they are found, because the organisms may be present in numbers on a perfect unmutilated leaf, and because no leaves occur that display alterations saving such as are made by insect larvæ. Secondly, the animals go to the ground to feed, as described in the foregoing paragraphs. Thirdly, the stomach-contents of active and newly killed snails comprise no fresh vegetable material, but only the rasped fragments of decaying woody and fleshy plant tissues. Again, animals that were feeding under observation in nature avoided the living parts of plants and restricted themselves to decaying leaves and wood. Finally, the specimens that were brought back to the laboratory ate moist dead leaves with avidity; only when very hungry did they eat the whiter and firmer portions of lettuce and cabbage leaves. In transporting them from the field, they consumed great quantities of wet paper, which, to all intents and purposes, is wood pulp. Dall has suggested that in the case of *Achatinellidæ* decaying vegetation is eaten for the sake of the fungi that grow in and upon it. Whether or not the same is true for *Partulæ*, the fact remains that the nurse-plants upon which *Partulæ* are found during the day do not seem to have any effect upon the specific or varietal characters displayed by these animals. We would scarcely expect that this would be so, when representatives of three distinct species may be sealed up on a single leaf of caladium, plantain, or *Dracæna*.

The food of ground-snails seems to be the same as that of the lower arboreal types. To what extent that of the *P. attenuata* series may differ or may agree remains for further determination; but, by analogy, it would consist of what the snails might find on the woody twigs and branches of the tree-tops.





Dense vegetation of the interior areas of the valleys, habitable for *Partulae*. (Photo Gauthier).





## CHAPTER II.

### THE COLLECTIONS FROM TAHITI AND THEIR INVESTIGATION.

#### THE SPECIES OF TAHITI.

In the course of the present research, Tahiti has been visited four times for the collection and observation of the snails. In the hot and wetter season of 1906 (February and March), all of the available time was devoted to this island alone. During June and July of the following year many more valleys were explored and some time was given to a first study of Moorea, although the field-work of 1907 was curtailed owing to illness caused by the tropical conditions. In 1908, during three months of the drier season, certain important valleys of Tahiti were revisited and a comprehensive survey was made of the Leeward Islands—Raiatea, Huahine, Tahaa, and Borabora. Finally in 1909, in the corresponding time of the year, the collections from Tahiti were again amplified by series from certain critical localities, while those from Moorea and Raiatea were also extended materially. In general, the Tahitian series fall into two seasonal groups, taken respectively during the wet and during the drier periods.

The investigation of the rich material entails, in the first place, a close study of the species and varieties as they exist in the different localities; secondly, a comparison of the present situation with what has been described for earlier times by other authors; the latter involves an acquaintance also with the authoritative collections in various museums, which has been gained through visits to the institutions at Honolulu, London, Paris, Berlin, Dresden, and elsewhere. One great difficulty is the confusion in taxonomy and identification that has resulted from inaccurate knowledge both of the localities from which shells have come and of the exact specimens that have served various authors as their types. The effect of this confusion is greatly reduced by relying upon the fundamental work of Garrett, to be described hereafter.

The first *Partulæ* were collected by Captain Cook's staff during his famous visits to Polynesia; they are *Partula faba*, described as *Limax faba* by Martyn in 1784, and *P. otaheitana*, which was named *Bulimus otaheitana* by Bruguière. The voyage of the *Coquille* yielded two species that were described by Lesson in 1830, viz, *Partula lutea* from Borabora and *P. lineata*, of which the latter was erroneously assigned to the Caroline Islands instead of to Moorea, its true habitat. Quoy and Gaimard in 1832 described certain dextral forms of *P. otaheitana* as *Helix vanicoronsis*, but attributed them to Vanicoro, an island of Melanesia. Subsequently Cuming explored the Society and other islands and sent back his shells to be named by Broderip, Reeve, and Pfeiffer, but unfortunately the true localities were not given, or were wrongly stated in at least two-thirds of the cases.

But, above all others, the name of Garrett stands out preeminently. He visited many groups of islands during his sojourns in Polynesia from 1860 to 1863, and from 1870 to the time of his death at Huahine in 1888; the rich fruits of his masterly studies are the shells that were described mainly by Pease and the precise description of their habitats specified with an exemplary minuteness of detail in his own notable monograph.<sup>1</sup> It is this work of Garrett's that forms a solid basis for the comparison of the present intrinsic and distributional characters of Polynesian species with their earlier conditions and situations.

Since Garrett's time no new species have been added to the Society Island list, but much discussion has proceeded with reference to specific and varietal characters and relations, with the above-mentioned confusion as its main result. Hartman<sup>2</sup> especially concerned himself with the genus *Partula*, but his lack of acquaintance with the living animals and with their habitats led him into errors that might have been avoided by a reliance upon Garrett's knowledge.

Mayer,<sup>3</sup> in 1899, made a most illuminating study of certain species of Tahiti, treating their distributions from the modern evolutionary standpoint. He made use for the first time of the embryonic young for the analysis of the species and varieties existing in the six valleys with which he dealt. It was Mayer's brilliant work, and his personal advice, that led the present writer to undertake the extensive and intensive studies on Polynesian *Partulæ* that are described in these memoirs.

In the fundamental Manual of Conchology, parts 79 and 80, Pilsbry has dealt at length with the genus and has given full quotations from Garrett, Mayer, and earlier authors. As a formal and complete record of taxonomic details, Pilsbry's work leaves nothing to be added in the present monograph. On certain minor details of relationship, however, my own studies lead to slightly divergent views, undoubtedly because the richer material in my own hands reveals facts which would not be manifest without it.

The absolute and relative numbers of snails belonging to the six species of Tahiti under investigation, collected in the several valleys, are given in table 9; the total number of adults and of adolescents are 24,085 and 7,194 respectively. It is true that several hundred more were obtained in several instances, most of which were returned to their environment after being scrutinized, while a few score of "dead" shells were collected; these do not form part of the series that was analyzed in detail, nor do a few others that were taken only to be discarded on one account or another, such as an injury to a label that made their locality doubtful. The embryonic young numbering several thousands do not figure in the table. A few additional gullies of small size were explored, but either they were barren of *Partulæ*, like St. Mau Fenua, or afforded only a few individuals of no particular worth, as in the case of Vaipupu in Punaauia.

<sup>1</sup>Garrett, Andrew: The Terrestrial Mollusca inhabiting the Society Islands. Journ. Acad. Nat. Sci. Philadelphia, Vol. IX, second series, part I, 1884. Unless otherwise specified, future references to Garrett's work relate to this monograph.

<sup>2</sup>Cf. Hartman, W. D.: Observations on the Genus *Partula* Fér., Bull. Mus. Comp. Zool., Cambridge, Vol. IX, No. 5, 1881. Also, on Hartman Collection, Smith, H. H.: An Annotated Catalogue of Shells of the Genus *Partula* in the Carnegie Museum. Annals Carnegie Museum, Vol. I, No. 3, XVII, 1902.

<sup>3</sup>Mayer, A. G.: Some Species of *Partula* from Tahiti—A Study in Variation. Memoirs Mus. Comp. Zool., Cambridge, Vol. XXVI, No. 2, 1902.

CRAMPTON

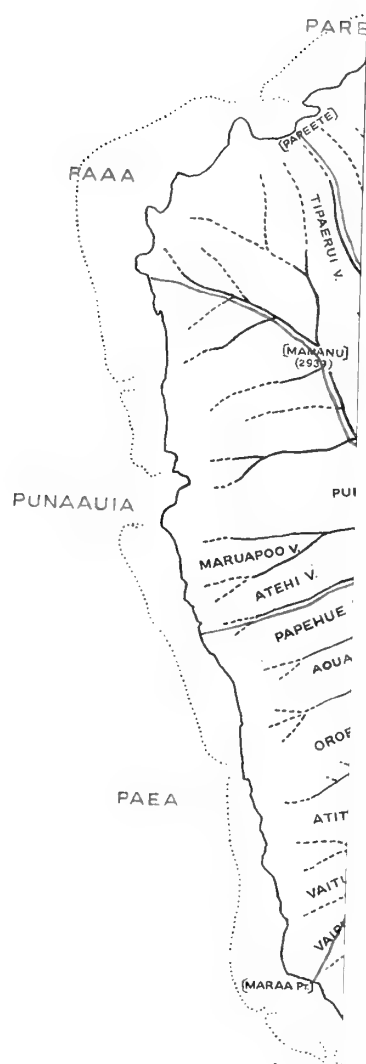






Zenith view of topographical model of Tahiti, constructed on the basis of charts, photographs, and observation. The greatest length of the land-mass as modelled (N. W. to S. E.) is about 44 inches: the vertical scale is twice that of the horizontal extent.











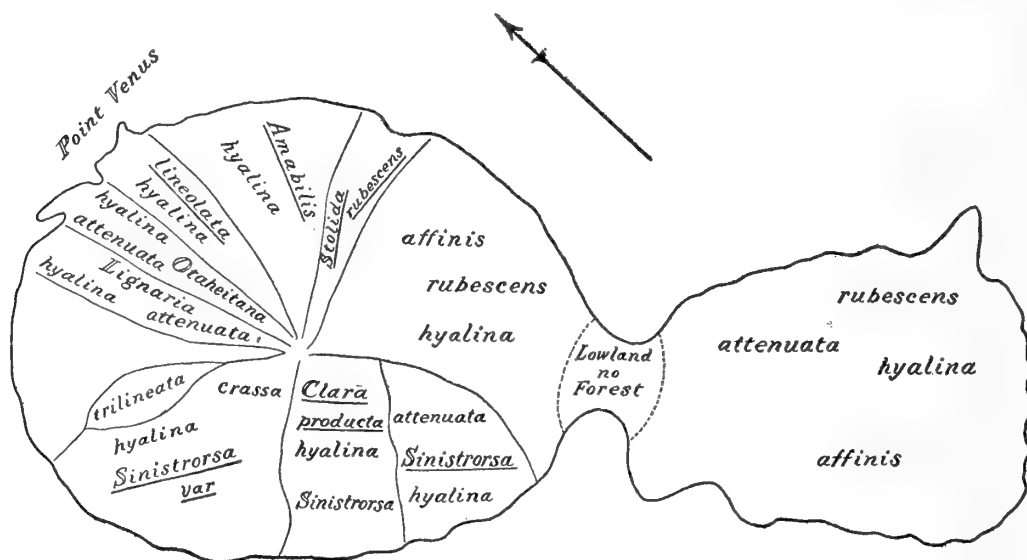
The principal topographical data are indicated in black (names of valleys, mountain ridges, and mountain peaks).  
The names and boundaries of the geographical or administrative districts are given in red.



TABLE 9.—Census of the collections.

District.	Valley.	Order of size	Number of adults.						Number of adolescents.						Per cent of adult population.								
			Total.	hyalina.	clara.	filosa.	nodosa.	otahaitana.	producta.	Total.	hyalina.	clara.	filosa.	nodosa.	otahaitana.	producta.	hyalina.	clara.	filosa.	nodosa.	otahaitana.	producta.	
Northern quadrant—	Papenoo...	I	546	39	5			502		231	11	4			216		7.14	0.91			91.94		
		III	313	1				312		90					90		0.31				99.68		
	Mahina...	II	300	5				295		103					103		1.66				98.33		
		II	388	14				374		104	6				98		3.60				96.39		
	Pare-Arue	III	346	1				345		91					91		0.28				99.71		
		III	391	4				387		88	2				86		1.02				98.97		
		II	1,254	55		211		988		626	85		41		500		4.39		16.82		78.78		
		III	484	10				474		222	8				214		2.06				97.93		
	Faaa.....	I	1,084	129				955		508	112				396		11.90				88.09		
II		959	22				937		402	45				357		2.29				97.70			
Western quadrant—	Punaauia.	II	551	13			313	225		138	19			91	28		2.36			56.80	40.83		
		I	756	7	6		186	557		256	4	2		104	146		0.92	0.80		24.60	73.67		
		IV	945	11	4		795	135		159				148	11		1.16	0.42		84.12	14.29		
		IV	450	11	22		4	413		105	2	10			93		2.44	4.89		0.89	91.77		
	Paea.....	III	392	4	35		210	143		84	1	15		16	52		1.02	8.93		53.57	36.47		
		III	1,132	19	67		396	650		242	4	7		115	116		1.67	5.92		34.98	57.42		
		II	266	2	49		18	197		34		5		10	19		0.75	18.41		6.77	74.06		
		III	190		36			154		23		6			17			18.94			81.05		
		III	365		44			321		46		9			37			12.05			87.94		
		III	204		24			180		100		6			94			11.76			88.23		
Southern quadrant—	Papara....	IV	350		24			326		90		17			73			6.85			93.14		
		II	163		33			130		105		60			45			20.24			79.75		
		IV	132		3			129		31		1			30			2.27			97.72		
		IV	382	22	13			347		87	4	5			78		5.75	3.40			90.84		
	Mataiea...	IV	163	3	8			152		36	3	2			31		1.84	4.90			93.25		
		IV	32	1	1			30		5					5		3.12	3.12			93.75		
		IV	63		1			62		5					5			1.58			98.41		
		I	573	5	5			563		73	1	4			68		0.87	0.87			98.25		
		I	488	4	9			475		180	1	9			170		0.82	1.84			97.33		
		IV	500	1	40			459		85		5			80		0.20	8.00			91.80		
		II	329	2	2			325		239	2	3			234		0.60	0.60			98.79		
		II	461		27			434		194		15			179			5.85			94.14		
	Papeari...	II	508	2	10			467	29	376	1	11			358	6	0.39	1.96			91.93	5.71	
		I	342		95			247		163	1	7			155			27.77			72.22		
		I	396	1	92			303		223	3	44			176		0.25	23.23			76.51		
		IV	207	1	3			203		28	3				25		0.48	1.44			98.07		
Eastern quadrant—	Hitiaa....	II	935	9	19			907		158	2	8			148		0.96	2.03			97.00		
		II	260	3	12			245		101	1	5			95		1.15	4.61			94.23		
		II	301	8	2			291		101	1	1			99		2.65	0.66			96.68		
		IV	313	5				308		95					95		1.59				98.40		
Tairarapu—	Pueu.....	III	599	2	3			594		46	1				45		0.33	0.50			99.16		
		III	351	2	2			347		40					40		0.56	0.56			98.86		
		II	284	6	3			275		88	2	1			85		2.11	1.05			96.83		
		IV	12					12		5					5						100.00		
	Mahaena.	II	712	23	21			668		132	5	3			124		3.23	2.94			93.82		
		IV	409					409		16					16						100.00		
		II	152	2	3			147		18		1			17		1.31	1.97			96.71		
		III	167	1				166		35					35		0.59				99.40		
	Tiarei....	IV	366	12	1			353		51	2	1			48		3.28	0.27			96.44		
		III	600	9				591		30					30		1.50				98.50		
	Vairao....	Tautira...		318	11	1			306		20	3	2			15		3.46	0.31			96.22	
				337	24	40			273		119	1	2			116		7.12	11.87			81.00	
				316	17	10			289		78		6			72		5.38	3.16			91.45	
				19	4				15		5					5		21.05				78.94	
		Teahupo..		224	4	1			219		60					60		1.78	0.44			97.77	
				20	2	2			16		6					6		10.00	10.00			80.00	
			46	1				45		7					7		2.17				97.82		
			169	7	17			145		56	8	9			39		4.14	10.06			85.79		
Haoma....			172	2				170		33					33		1.16				98.83		
			273	26	22			225		152	17	9			126		9.52	8.05			82.42		
Quadrant—	Northern..		272	13			259		162		1			161		4.77				95.22			
			53	7	2		44		8	6				2		13.21	3.77			83.01			
Tahiti nui...	Tairarapu....	10 valleys	6,065	280	5	211		5,569		2,465	269	4	41		2,151		4.62	0.08	3.47		91.82		
		10 valleys	5,251	67	287		1,922	2,975		1,187	30	60		484	613		1.28	5.46		36.60	56.65		
		20 valleys	6,898	67	399			6,403		2,375	23	197			2,149	6	0.97	5.78			92.82	0.42	
		10 valleys	3,652	57	33			3,562	29	461	10	6			445		1.56	0.90			97.53		
Total .....	62 valleys		21,866	471	724	211	1,922	18,509	29	6,488	332	267	41	484	5,358	6	2.15	3.31	0.96	8.79	84.65	0.13	
			2,219	118	95			2,006		706	35	29			642		5.31	4.28			90.40		
			24,085	589	819	211	1,922	20,515	29	7,194	367	296	41	484	6,000	6	2.44	3.40	0.87	7.98	85.18	0.12	

While the full list of recorded Tahitian species numbers 8, the present study is concerned with 6, all of which provide most significant data for the problems of distribution and evolution, although no two of them agree in the details of their occurrence and variation. *Partula hyalina* Broderip is a small arboreal species with a white shell that exists all about the island without variations in color, although it is far from uniform in size and shape, as it has been supposed to be; the same species occurs in the Cook and Austral Islands. *Partula clara* Pease is also an arboreal species with a small shell that now ranges over about three-fourths of Tahiti, although it was formerly more restricted in its territory; it exhibits an interesting condition of differentiation into subordinate types that are well on their way toward the status of subspecies. In sharp contrast with these two, *Partula filosa* Pfeiffer is confined to a single valley in the drier northern section of the island, although in this one area it varies greatly in size and color. *Partula otaheitana*

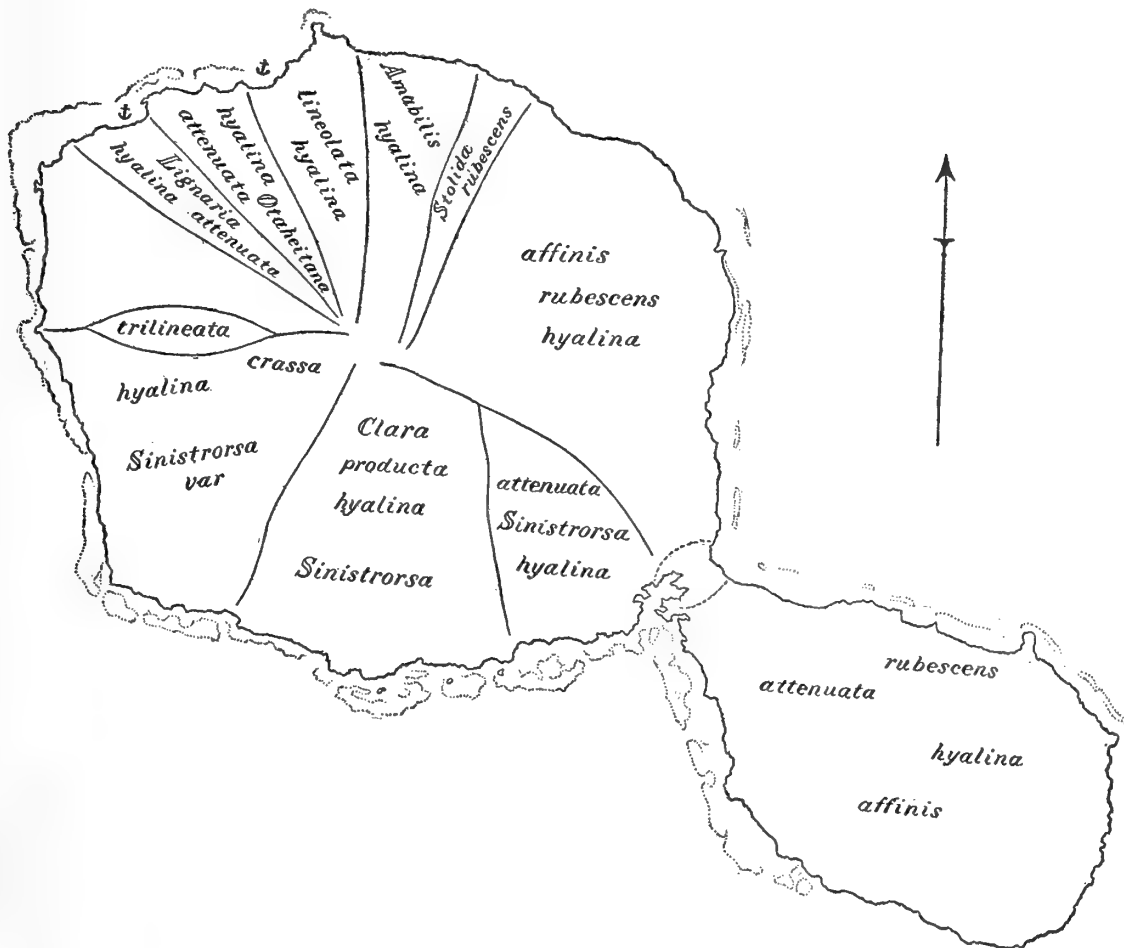


TEXT-FIG. 2.—Garrett's chart of the distribution of Tahitian *Partulae* in his time, as published in Hartmann's paper. Original form and lettering.

Bruguère forms the vast bulk of the whole population, existing in unusual numbers in every habitable valley of the island; it has differentiated into 8 subspecies of closer or wider affinities, and in its entirety it affords ideal material for the analysis of the problems under consideration. The sixth species, *Partula producta* Pease, differs from the foregoing in its terrestrial habit; it has been found in one valley only, and hence it adds little of interest for the problem of distribution. Like the last-named, *Partula stolidus* is described by Garrett from Papenoo Valley only, where, however, I failed to discover it in spite of repeated efforts; some confusion exists in the identification of this form, which is referred to *P. compressa* by Pilsbry, although the true *compressa* is a variety of the Raiatean species *P. radiata* Pease, in the opinion of Garrett and myself. Finally, in Tahiti and also in Raiatea occurs the arboreal species *Partula attenuata* Pease, where it lives among the top-most branches of the trees; only two or three specimens were secured in Tahiti,

which are quite useless for the purposes of the present study. Certain other Tahitian references exist in the literature, but the forms so recorded are either varieties or are erroneously attributed to Tahiti.

The distribution of the Tahitian species during the last quarter of the nineteenth century is known from Garrett's detailed monograph. In addition he drew a map showing their general localization, which map was published with a paper by Hartman; this chart, in its original and in rectified form, is given in text-figures 2 and 3, and is a graphic record to which reference will be made at many points in the following analysis.



TEXT-FIG. 3.—Corrected form of Garrett's chart (text-fig 2) showing the distribution of Tahitian Partulæ in his time. Original lettering.

#### THE GEOGRAPHY AND TOPOGRAPHY OF TAHITI AND OF THE AREAS OF HABITATION.

We must now consider in some detail the general and special topographic features of Tahiti in order to define the degrees of proximity or isolation of areas whose species and varieties are subsequently to be described and compared. The valleys from which specimens were taken are listed in table 9, which also gives their location in the geographical or administrative districts, and in the major sections of the whole island. In order to bring out the essential topographical features, a model about 4 feet in diameter has been constructed by members of the

technical staff of the American Museum of Natural History, under the close supervision of the author; plates 9 to 15 show the various aspects of this model from the zenith and from the cardinal points of the compass, together with outline keys. In addition, the photographs of plates 5, 6, 7, 8, 15, 16*a*, 17, 18, and 19, illustrate the topographical and other features of representative valleys. The table and plates are sufficiently comprehensive to define correctly the essential facts that are related in the following systematic description.

The two extinct volcanic cones of which Tahiti is composed are undoubtedly of ancient origin, as their rugged centers and slopes indicate. These cones have been weathered so as to be furrowed by radiating valleys of greater or less width with steep or gradually sloping sides. The firmer rocks that have resisted weathering and the masses of greater original height form the buttresses and intervening ridges, which rise to nearly perpendicular pinnacles in the central parts of both divisions of the island. The softer materials have been washed down by the almost daily rains to form a coastal plain or shelf that may be but a few yards in width or that may extend back for a mile or more in the radii of the larger valleys. From a few yards to a half mile outside of the shore-line runs a living coral reef which is interrupted only here and there, so that nearly everywhere the coastal plain is protected from the wash of the powerful waves; fringing reefs also occur at several points on the coast.

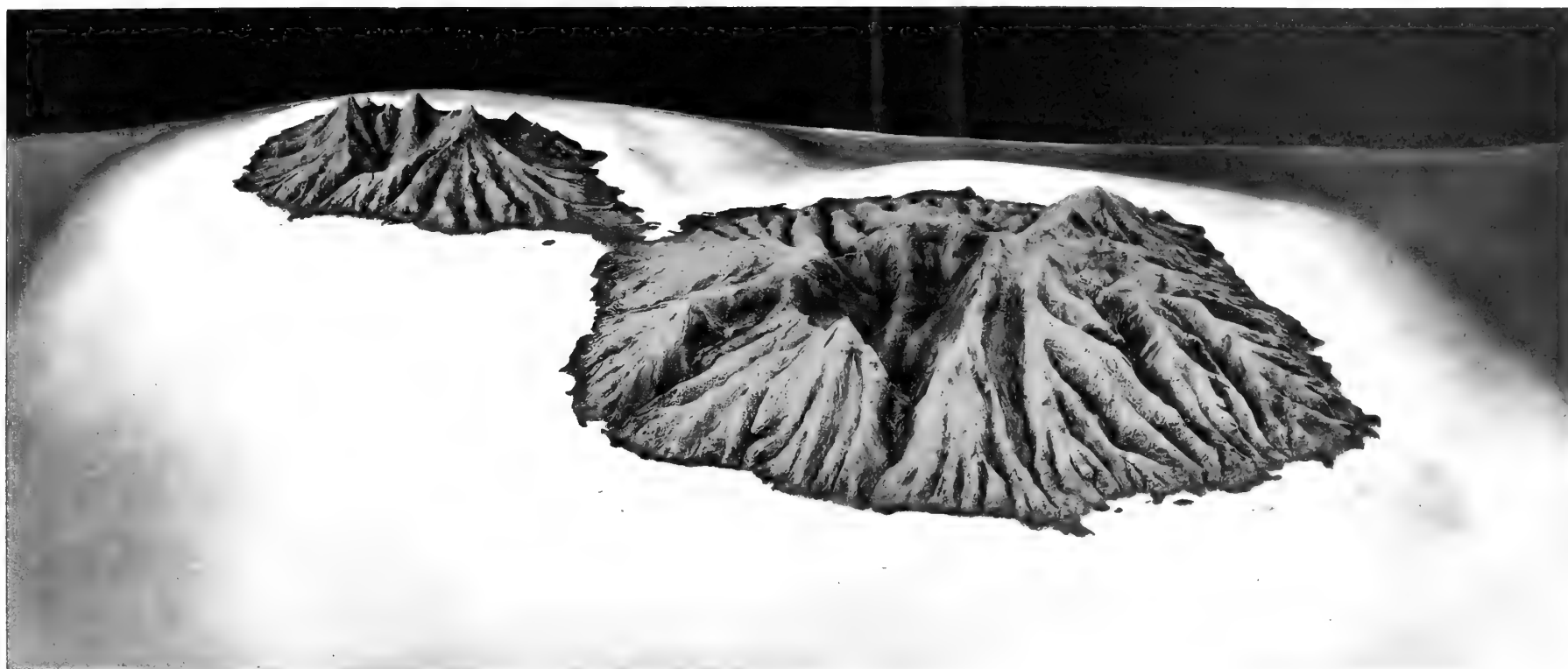
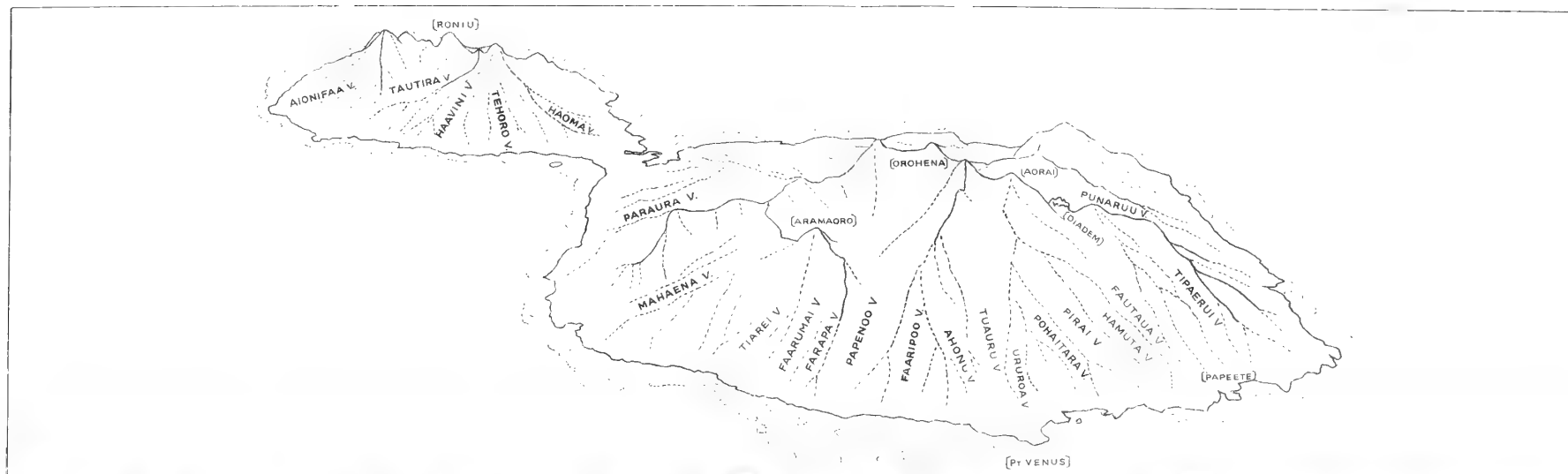
In Tahiti nui the main peak reaches an altitude of approximately 7,500 feet, while other peaks near the center range from about 5,000 to 2,500 feet. The central portion of this division of Tahiti, within a circle drawn about 6 miles back from the coast line and concentric with it, is extremely rough, for in this area were the principal and secondary vents of the ancient volcanoes, now partly filled, but forming deep hollows between and among the steep-sided and sharp-pointed peaks. By weathering, however, the sides of these craters have been cut so as to give outlet to the waters that might otherwise have collected to form lakes, although one exception occurs, namely, Lake Vaihiria, 2.5 miles due southwest from the geometrical geographical center of the island, at an altitude of over 1,400 feet. These great outlets that appear from a distance offshore as huge clefts in the sides of the cone form valleys of a primary order that communicate centrally, though at relatively high altitudes and in no direct manner. There is no central plateau, and steep ridges of considerable height must be crossed in passing from the head of one primary valley to another.

For administrative purposes, the island is divided into 19 districts—14 in Tahiti nui and 5 in Tahiti iti or Taiarapu. The boundaries of these sections are marked by prominent topographical features in the way of high peaks and ridges forming the borders of primary and secondary craters, as well as major divides that radiate outwards from the center. For instance, Papeenu is bounded on the west by the lofty border of Tetiari Valley near the coast and of Papeenu Valley itself further inland; the border-line culminates in Orohena (7,321 feet), and follows the contour of the great crater southward and eastward to the peaks of Tetufera (about 6,000









Nothern aspect of topographical model of Tahiti, with outline key.







feet), eastward and northward to Aramaoro (4,848 feet), and thence to the coast along the ridge bordering Faarumai Valley on the west. Papara is bounded on the west by the ridge beginning at the southwestern corner of Tahiti nui that rises to Mount Ivirairai (5,556 feet), and to Mount Mahutaa (4,943 feet), and continues on to join the southern border of the great Papenoo basin; the eastern boundary runs coastwards from Mount Tetufera along a prominent ridge. In general, each political district includes at least one large valley as a salient topographical feature, and consequently each administrative section is also an ecological region centering about the deep valley area or areas.

In another way, the island is divisible into sectors of high land that lie between the major valley clefts. To the west of Papenoo Valley, one such sector rises to the highest peaks, Mount Orohena and Mount Aorai, and ends beyond at Fautaua Valley; in this there are many valleys of lesser extent and depth which fail, however, to reach the center so as to articulate with either Papenoo or Fautaua. Between the latter and Punaruu Valley is another sector in which are located Tipaerui (plate 15*a*) and Taapuna, as well as lesser elements. From Punaruu to Temarua the land-mass is extremely regular and is somewhat distinctly divided by Orofere Valley into northern and southern components. The next sector extends to Vairaharaha and Vaihiria, and contains many long, narrow valleys. So the rest of the whole island is organized into land-masses and lesser valley systems, in ways that are sufficiently indicated by the illustrations, or that may be described in further detail in the discussion of a given species or variety and its distribution.

Taking a more general view of the whole of Tahiti nui, it is convenient to divide this land-mass into four major quadrants that form as many well-defined ecological sections, so far as their general climatic conditions are concerned. The line running from the Isthmus of Taravao at the extreme southeast to Motu Tahiri at the northwest coincides with the direction of the prevailing winds laden with moisture. A line at right angles to this, viz, from Maraa at the southeast to the district of Tiarei at the northeast, completes the partition of Tahiti nui into quadrants and defines the boundaries between the wet southern and eastern sectors on the one hand and the drier western and the driest northern regions on the other. For purposes of convenience in the detailed description, however, the point of contact between the eastern and northern quadrants is shifted to the west, so as to lie between Farapa and Papenoo Valleys.

It has been stated that lesser ancient vents lie outside of the main central region, from which run deep valleys of a secondary order, such as Tipaerui (plate 15*a*). Naturally the valleys of this grade are more isolated from one another and from the primary elements as well. Many of them do indeed reach inland for a considerable distance, but their side ridges are much higher and steeper than in the case of primary valleys. Between the valleys of the second order are still others of lesser radial extent (*e. g.*, Papehue Valley, plate 15*b*), but still large enough to collect streams of some size. Like the larger ones, these tertiary elements also differ much in radial extent and in the heights of their sides, in which they are cut. It is possible to recognize also elements of a fourth order (plate 16*a*), while finally there are

the shallow depressions between contiguous ridges that bear no streams or do so only in times of exceptionally heavy rains, as in the subsidiary sector behind Papeete (plate 15*a*).

In the tables and descriptions, the grades assigned to the several areas of collection have been given on the basis of size and extent according to the best judgment of the present writer, although another observer might attribute different relative values to the valleys. Certain anomalies appear, it is true: Maruapoo, which is deep vertically and short in its inland extension, is put in the same class (fourth order) with Opiriroa, a longer and narrower valley of the southern quadrant; yet the areas inhabited by snails are more similar in character and extent than are the topographical features of these two valleys. Again, Papenoo is assigned to a series of first-order areas, although in extent it greatly exceeds Fautaua (plate 5*a*), Punaruu (plate 19), etc.; but it would scarcely be convenient to establish a separate order for this single greatest valley element of the island. In brief, the assigned grades may be employed as useful indices of size, even though they may be merely approximate.

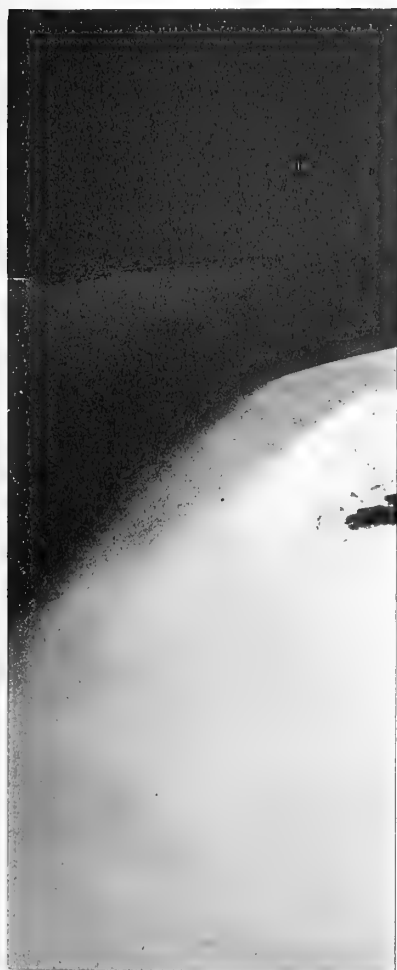
Tiarapu or Tahiti iti, the peninsula, is connected with the larger portion by a strip of land of low altitude about a mile in width, the Isthmus of Taravao. In its structure the peninsula reproduces on a smaller scale the features of Tahiti nui (plate 6*a*). On account of its lesser area the single primary valley, Tautira, communicates more readily with the elements of the second order, such as Haavini, Hototunu, etc., although even here the divides are of considerable height.

The list of valleys from which *Partulæ* have been obtained is given in table 9. Doubtless there are others in which these snails occur, but the exigencies of the field investigation were such as to render the exploration of all of the lesser gullies impossible, especially in parts of the eastern quadrant and in Taiarapu. While it is conceivable that minor varieties might be brought to light through further investigation, yet the list of 62 valleys undoubtedly covers the field satisfactorily and certainly gives a basis for a positive and extensive description of the conditions and situations of the forms existing in this island.

The nomenclature of the areas of collection is not a simple matter, because as many as three or even four names for a single valley may be employed by the natives. Sometimes the name of a district will be applied to its single major valley, as Punaauia for Punaruu Valley; the name of the river is not always the same as that of the valley for which it is often employed; again, an inland area may be designated by the village that lies at its mouth. Furthermore, old names will be replaced by new ones, as in the case of Orofere, which is now called Faarahi, whereas Garrett speaks of it as Faahuaite. The names given in the present list are well known in usage, and no confusion need arise, because all valleys under discussion are definitely located in the charts accompanying this section and the verbal description given later; the essential matter to be safeguarded is such an accurate specification of the areas of collection that investigators of decades to come may identify the places whose forms are analyzed in the present monograph.

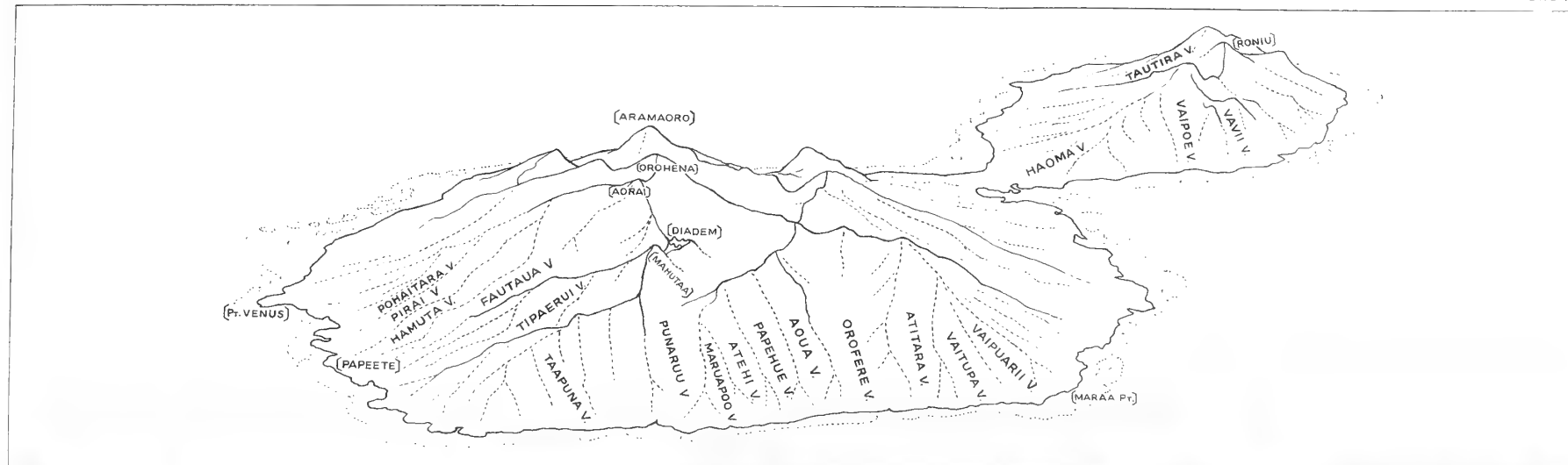
CRAMPTON

Pt. VEN









Western aspect of topographical model of Tahiti, with outline key.



## THE COLLECTION, TREATMENT, AND ANALYSIS OF THE MATERIAL.

Field-work in such a region as Polynesia presents difficulties that are common to most tropical areas in the way of access, climate, and travel about the islands. As a rule, steamship lines ply between only the principal ports, from which excursions to neighboring islands must be made by cutter, whaleboat, or canoe. The same means must also be employed in journeying about the periphery of a single island, although at times it is possible to procure horses, as in most of the work in Tahiti. Almost without exception, however, the exploration of a valley can be accomplished only on foot, owing to the steep declivities to be traversed, the deep streams to be forded, and the absence of any trails whatsoever in the thick forest and undergrowth of the areas inhabited by *Partulæ*.

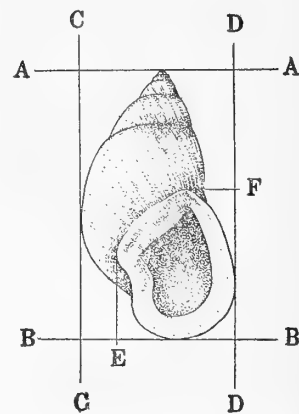
It was my custom to start in the early morning with two or three native assistants, more rarely alone, and to spend the greater part of the day in the interior. Full notes were made as to the character of the vegetation, the favored nurse-plants, the topographical features, the inland distances and barometric levels of the points where snails were first met and of their headquarters in a given valley, as well as other pertinent facts. The experiences incidental to the active life necessitated by such work were many, varied, and interesting; but the present monograph is not the place for a description of the beautiful islands or of their delightful inhabitants. Suffice it to say that the days and nights of arduous and sometimes dangerous effort included hours of keen enjoyment, for the island of Tahiti, especially, is of matchless beauty, while the chiefs and their families offered abundant hospitalities which it was a privilege to enjoy at the time as it is now a pleasure to acknowledge them.

Having secured the snails, the return to the coast was made, and the animals were put in glass jars filled with fresh water so as to exclude the air. After a few hours, the animals were expanded in an asphyxiated condition, whereupon formalin in due quantity was poured in as a preservative. Alcohol alters the color to some extent, while formalin does not. Care must be taken to free the material from foreign bodies, such as bits of leaves or sticks, and to keep the preservative from contact with metal, else the colors of the shells will be altered by the decomposed or otherwise changed fluid.

The exigencies of field-work do not permit more than a cursory study of the material before it is brought back to the laboratory where analytical work begins. Carefully segregated, valley by valley, the snails are then classified according to species, variety, and class or subordinate variety. Often the assortment into constituent groups must be repeated on the basis of what may be discovered in the study of a neighboring colony. Then follows the time-consuming labor of measuring the shells, arranged serially in divisions according to their qualitative characters; the dimensions were measured to tenths of a millimeter. At the same time that such quantitative data are obtained, the more or less extended body of the animal is extracted, and if the individual is gravid, the number of eggs and young snails is noted, as well as the data relating to the color and coil of embryonic shells. The adults are then marked with their serial number, so that later reference may be made to any individual shell should occasion arise. The author is personally

responsible for every direct measurement and for every detail of classification; hence the personal coefficient is uniform throughout the entire research.

The quantitative characters chosen for determination and study are the standards of comparative malacology (text-fig. 4). They are (1) the greatest length of the shell including its lip (AA to BB); (2) the greatest width, also including the lip (CC to DD); (3) the proportions of the whole shell, viz, character 2:character 1; (4) length of the outside measurement of the aperture (point F to the line BB); (5) width of the aperture (point E to the line DD); (6) proportions of the aperture (character 5:character 4); (7) the proportion of aperture length to the length of the whole shell. Whenever a columellar tooth was present, it was noted as a "trace," as "average," as "large," or "very large," thus giving five classes, including the group in which the structure was lacking. In the end each adult shell bears a distinguishing number corresponding to a place in the primary tables where its description is given by specific data numbering from 10 to 14 or more, as the case may be.

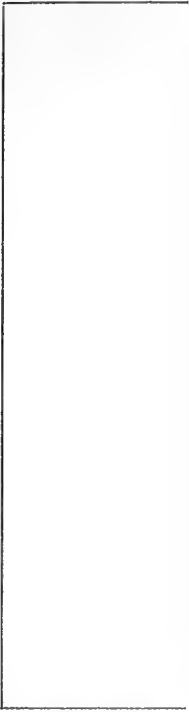


TEXT-FIG. 4.—Diagram of a *Partula* shell to illustrate the dimensions measured directly.

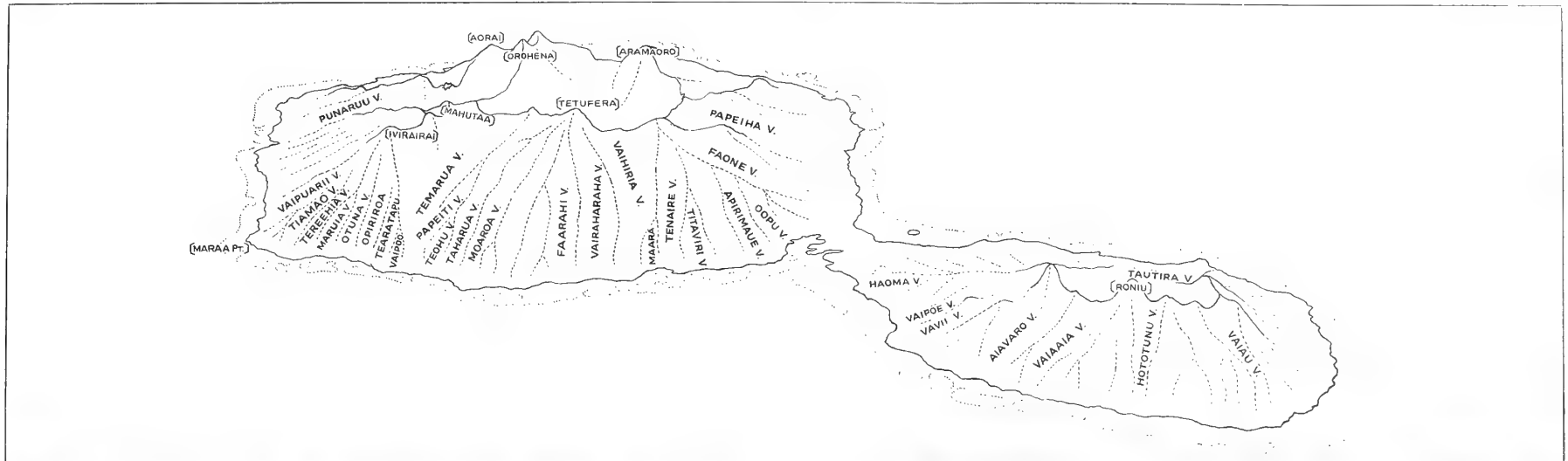
The dimensions and proportionate measures are then treated by statistical methods so as to derive the simplest terms for a collective description of a group; it is unnecessary to describe in detail the methods for the reduction of quantitative data, in view of their general currency in experimental work. The average or mean value is the first constant [M], and this is of course the sum of the classified measurements divided by the total number; it indicates the typical condition. The second constant is the standard deviation, or index of variability [ $\sigma$ ], which describes the degree of conservatism of the members of a group in relation to the average or mean condition; the individual deviations from the mean are squared and added, and the square root of this sum is the standard deviation. It is expressed in the same units as the average (millimeters or per cent). The measure of *absolute* variability, or coefficient of variation, is often employed in statistical description, as the index of variability divided by the mean value and multiplied by 100; in the present study, however, this coefficient has not been employed, because of the additional labor involved and because it may be readily obtained from the two fundamental data as given in the tables, by anyone who wishes to use it.

It must be added that the individual proportionate measures (characters 3, 6, and 7) were treated like the direct dimensions, as to many independent variates or data. While it is true that the *average* value of one of them, *e. g.*, the proportion of the shell, could be obtained by the short method of dividing the group average for width by the group average for length, it would be impossible to obtain the standard deviation of the relative measurement from other data than the individual determinations themselves. It happens at times that the average of the proportion does not agree *exactly* with the figure derived from the averages of the lengths and widths, for reasons which may best be understood by citing concrete cases. In

CRAMPTON







Southern aspect of topographical model of Tahiti, with outline key.





classifying the individual measures of length, those from 16.0 to 16.2 mm. inclusive would be combined in a class represented by 16.15 mm.; in classifying the measures of width, those from 9.00 to 9.19 would be grouped about the class value of 9.10. The individual proportions for 6 diverse shells would be as shown herewith: The proportional length and width of class values is 56.3 per cent. Now, all of the fractions of a percentage are referred to the half value of that figure, viz, 56.5 per cent, which would represent four of the six individual measurements given above, but not two of them. On the principle, however, that errors in opposite directions balance or neutralize one another in a large series of determinations, the discrepancies may be ignored. In the present study, to repeat, the individual proportions have been seriated and described by their independent constants, primarily to obtain the indices of variability. Should anyone demur to this procedure, he may obtain the alternative values from the figures relating to characters that were directly measured.

Length.	Width.	Proportion.
		<i>p. ct.</i>
16.0	9.0	56.2
16.0	9.1	56.8
16.1	9.0	55.9
16.1	9.1	56.5
16.2	9.0	55.5
16.2	9.1	56.1

In order to judge whether two component groups of one and the same colony are statistically alike, or whether two colonies of the same species which exist in neighboring valleys are identical, it is necessary to determine the probable errors of the descriptive constants. The probable error of the average ( $Em$ ) is  $0.67449 \times \sigma$ , divided by the square root of the number of cases. The probable error of the standard deviation [ $E\sigma$ ] is  $0.67449 \times \sigma$ , divided by the square root of twice the number of cases. Observing a numerical difference between the average values of a character, in two comparable groups, the difference must be judged as to its significance by its own error, which is the square root of the squared probable errors of the two average values. Should the difference in question exceed its error, but fall below twice the error, it is not significant; should it lie between twice and thrice its probable error, then presumably it indicates a real constitutional diversity; when it is greater than three times its probable error, then the existence of a real difference is a statistical certainty (995 out of 1,000 chances). In the numerical tables, differences that are only probable or possible are placed in brackets. It remains to be stated that in computing the standard deviation fractions were carried out to eight decimal places, in order that the four-place index should be as accurate as possible.

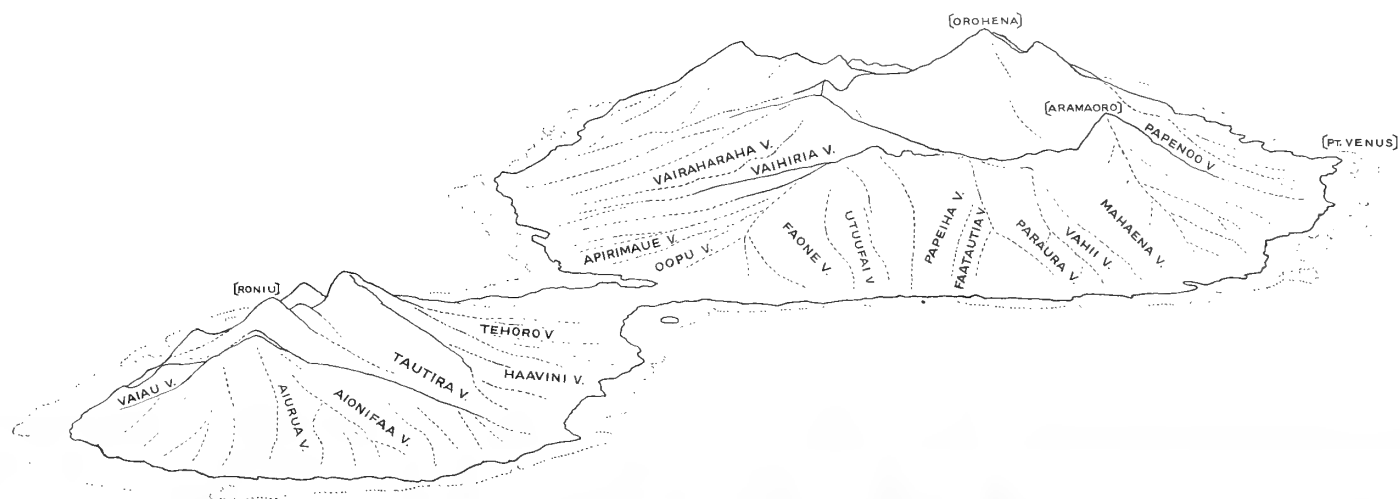
The length of time required for such quantitative analysis can be estimated only by those who themselves have engaged in such work. Even after the lapse of weeks and months devoted to classifying and measuring the shells, far more time must be occupied in the reduction of the data to the two simple constants of each series. These figures, together with a single line of text, may be all that represents two to eight weeks of mathematical drudgery, however this might be facilitated and lightened by the use of numerical tables and the calculating machine. Yet the employment of such methods is justified in the final results, which collectively give an accurate description of the species and varieties of *Partula* for the period of field-work.



CRAMPTON







Eastern aspect of topographical model of Tahiti, with outline key.



## CHAPTER III.

### PARTULA HYALINA Broderip.

#### GENERAL CONSIDERATIONS.

*Partula hyalina* is taken as the first species to be examined and analyzed in detail because it is an unusually distinct form possessing clear differential characters, set well apart from the other species of Tahiti. It is distributed widely about the island, but varies only in size and shape, so that its study is not complicated by the existence of diverse color-types. In one important particular, *hyalina* is a unique member of the genus, namely, in its occurrence in three distinct groups of islands—Society, Cook, and Austral—although not in all of the members of any one of these groups. This remarkable feature alone would render it of more than ordinary interest to the student of its natural history.

Broderip's description is dated 1832, thus making the species one of the first to be founded after *P. faba*, the type of the genus, was described by Martyn as *Limax faba* in 1784. The original account of *hyalina* is as follows:

"*Partula testa oblonga, hyalina, anfractibus sex, longitudinaliter levissime striatis et transversim minutissime creberrimeque lineatis; labro albo. long. 9/10, lat. 3/10 poll. Hab. in Polynesia (Oheataroa).*"<sup>1</sup>

The clear hyaline shell (figs. 1 to 13, plate 16) is universally devoid of color, and in this respect it is distinguished from all other species of the genus. It is invariably dextral. The absence of a pillar tooth is another diagnostic feature, although it is shared with other types, such as *P. arguta* of Huahine. Particular mention should be made of the delicate sculpturing of the surface, emphasized by Broderip in his original description; the lines of foveæ upon the embryonic shell are continued to the very limits of the mature and fully formed shell. The aperture is bounded by a flaring lip, which is often thickened inwardly, so as to reduce somewhat the size of the opening. The plane of this lip, or aperture, is markedly oblique to the axis of the shell, as in *P. clara*, also from Tahiti. Certain other characters are specified in the full taxonomic descriptions, such as that of Pilsbry, but the above diagnostic features will suffice for our present purposes. In a subsequent section that deals with the variation of the shell and with the phenomena of distribution, a more detailed description will be given on the basis of the quantitative determinations.

The following account of *hyalina* and its natural history is based primarily upon the material and observations obtained in Tahiti, which is the only one of the Society Islands in which the species occurs. Small collections were also secured in Mangaia and Moki, two islands of the Cook Group, where *hyalina* occurs. It was impossible to visit the Austral Islands, where Cuming collected the type forms for Broderip's study and description, in the island named Oheataroa (Oheatoroa of Captain Cook) now called Rurutu. It may be possible to secure specimens from the last-mentioned locality at a future date, but their lack at the present time is not

<sup>1</sup>Proc. Zool. Soc., 1832.

serious; the immediate task is to deal with the snails of the Society Islands, for this region is now the headquarters of the whole genus, both as regards the variety of species and the abundance of individuals.

In very few particulars does *hyalina* exhibit any peculiarities in its habits or its general ecological relations; these are essentially the same as in other *Partulæ*, already described in an earlier section. Like all other forms, during the day it usually remains sealed-up upon leaves or stalks of its habit-plants and crawls down to or near the ground at night for the purpose of feeding upon decaying vegetation. Sometimes during the day a heavy shower that drenches the vegetation of the valleys will cause the snails to resume activity, but the adults may not respond at all until the darkness of evening or night adds its accustomed influence. It does not seem to be necessary for the animals to be flooded by rain-water to bring about activity, during either day or night; primarily the rise of humidity in the former case and the absence of light in the latter acts as the stimulus to activity. Material brought to New York for observation in the laboratory displayed the same sensitiveness to moisture and dryness, light and darkness, which may be observed in the field.

The favored nurse-plant varies in different valleys. In Fautaua the "fei" (*Musa*, plantain) and 'ape (*Colocasia*) are more apt to bear *hyalina* than the citrus or larger timber trees. When *Dracæna* is in season, smaller snails are frequently found under its leaves. Wherever thickets of turmeric occur in a region inhabited by snails, they will furnish a higher proportion of *hyalina* than one can discover on the neighboring bushes and trees. But when all the observations are brought together there proves to be no single plant that is the universal favorite of this species of snails; the plaintain may be preferred in one valley, while in another place where this is equally abundant, other plants like the caladium will provide a richer collection of snails of this species.

One feature is worthy of note in view of certain considerations that will be stated in the subsequent general discussion of the occurrence of this species in limestone islands of the Cook Group. This feature is the preference of the snails for more open situations in the several valley areas where they live. Often the first *Partulæ* met in entering a valley belonged to this species, while in places such as the borders of the streams, where larger forest trees are fewer and there is more sunlight, the *hyalina* would be found more frequently than in the deeper and wetter shaded areas. They are not *confined* to the open areas and to the drier borders of the whole region of *Partula* habitation, but seem to tolerate conditions that are not preferred, at least, by the representatives of *P. otaheitana* and other species.

#### THE NUMERICAL DISTRIBUTION OF PARTULA HYALINA IN TAHITI AND ITS SIGNIFICANCE.

In my collections *Partula hyalina* was obtained from 51 valleys and proved to be absent from 11 localities of the entire series of 62 stations which bore snails of this genus. Garrett described the species as "distributed in limited numbers throughout every valley in Tahiti"; undoubtedly he did not take into account the smaller valleys and gullies investigated in the course of the present research, which



lack this species, while it is more than probable that on account of the island-wide distribution of the species he assumed the existence of *hyalina* in some of the larger valleys from which it now appears to be absent. Mayer is the only other author who has dealt with the distribution of this species, and he found it in all of the six valleys from which his collections were taken, namely, Pirai, Hamuta, Fautaua, Tipaerui, Maruapoo, and Vaihiria.

The general census (table 9) gives the exact numbers of *hyalina* taken in the several valleys, as well as their relative frequency, namely, their percentage value of the whole population. These figures relating to adult snails give as accurate a determination as possible of the relative abundance of *hyalina*, for there was no discrimination exercised in the collection of snails, except in two cases. The first exception is in the case of Pirai Valley, where in 1909 particular attention was paid to *Partula filosa*; on this occasion several hundred individuals of *otaheitana* were obtained and counted and were at once returned to their forest habitat. Another exception must be made in the case of Faarahi, to which a second visit was made in 1909 for the purpose of securing *producta*, when little attention was paid to the *otaheitana* peculiar to this valley, although all the *hyalina* and *clara* found were kept. Therefore the figures for these two valleys give only an approximate indication of the true frequency of *hyalina* in the local population.

From table 9 and summary it appears that *hyalina* contributes only 2.44 per cent of the adult *Partula* population of Tahiti. The figures relating to the partly grown snails show that the *hyalina* adolescents number 367 out of 7,194, or 5.10 per cent. The reason for the difference between the relative numbers of this species in adult and immature populations is discussed beyond, when the facts relating to fecundity are presented. For the present we may confine our attention to the figures for the adult individuals and the percentage of these consisting of *hyalina*. This percentage is far from uniform throughout the island, and the striking differences exhibited by various regions and valleys are not only of interest in themselves, but they are also of fundamental importance for the study of the larger problems under consideration. Specifically, such differences show that in different localities this species varies in constitutional vigor quite as surely as it does in morphological respects.

We may first compare the two primary divisions of the island, namely, Tahiti nui and Taiarapu. In the former, *hyalina* forms 2.15 per cent of the population as represented by the collections, while in the peninsula the corresponding figure is 5.31 per cent. The data for Taiarapu are rendered somewhat unreliable by various circumstances, chief of which is the lack of large and representative collections from several valleys. In Aionifaa only 19 adult snails were secured and 4 of these were *hyalina*, thus giving a value for this species of 21.05 per cent; this figure is almost certainly misleading. Again, the series of twelve valleys located in the peninsula from which collections were obtained is so small, and the ecological conditions vary so much in its different quarters, that there are not enough data to serve for a thorough analysis of this district. Hence Taiarapu may be disregarded in the further discussion of the numerical distribution of *hyalina* in Tahiti.

Restricting our attention to Tahiti nui, we may group the valleys according to their location in one or another of the four primary quadrants, which, it has been shown earlier, constitute four well-marked ecological regions. The figures prove that *hyalina* is most abundant in the northern quadrant (4.62 per cent); the eastern section has 1.56 per cent, the western 1.28 per cent, and the southern section bears but 0.97 per cent of this species. The differences indicated might conceivably be due to a relative scarcity of other species in the northern quadrant and to their relative abundance in the southern section, where *hyalina* forms a smaller percentage of the total population, even though the latter might actually be uniform in its frequency throughout the island. This possibility, however, can be set aside in a simple way. As a given collecting trip in any valley was approximately equal in length of time to that made in another valley, and as the conditions of weather were sufficiently uniform to be disregarded as qualifying factors, we may determine the average number of *hyalina* procured in a collecting trip of average duration in each of the four main sections. The data are as follows:

Region.	No. of <i>hyalina</i> .	Collect ing trips.	Average number for one trip.
North quadrant....	280	21	13.3
West quadrant....	67	14	4.7
South quadrant....	67	22	3.0
East quadrant....	57	10	5.7
Tahiti nui.....	471	66	7.1
Taiarapu.....	118	13	9.0
Whole island.....	589	79	7.9

The figures render it certain that in absolute numbers and not merely in relative frequency the species is most abundant in the northern quadrant, and least abundant in the same sense in the moist southern section of Tahiti nui. Particular emphasis is laid upon these relations on account of the exactly opposite conditions exhibited by *P. clara* described in Chapter IV.

A still closer scrutiny of the data reveals a much more striking lack of uniformity in distribution. When the relative numbers of *hyalina* occurring in different valleys are compared, great variation is found to exist even among localities in one and the same quadrant; in fact, parallel and neighboring valleys often exhibit most significant contrasts. Certain examples may be cited. In Fautaua Valley this species exists in greatest relative abundance, forming about 12 per cent of the whole population; it is interesting to note in passing that this locality is also the headquarters of the most generalized varieties of the complex species, *P. otaheitana*. In the neighboring valleys of Hamuta, a half mile or less to the east of Fautaua, and Tipaerui, 2 miles to the west, *hyalina* forms only 2.06 per cent and 2.29 per cent of the populations, respectively. Collections from the great valley of Papenoo contain 7 per cent of *hyalina*, while in Faaripoo, the next valley to the west of Papenoo, only 1 *hyalina* was obtained in a series of over 300 snails. Again, Paraura Valley in the eastern quadrant bears 3.23 per cent of *hyalina*, but in the nearest neighbor, Vahii,

the species was lacking in a collection comprising 409 adult specimens. In 11 valleys it was impossible to find a single example of *hyalina*, either full-grown or immature.

It is certain, then, that this species is absolutely more abundant in some valleys than it is in others, even though it appears that a higher proportion is indicated for the valleys from which the largest collections were obtained, like Fautaua. It is only a coincidence that *hyalina* should happen to be more numerous in certain valleys to which several excursions were made on account of special interest in other species.

TABLE 10.—Percentage of *hyalina* in relation to size and location of valleys. Tahiti. Full data.

Region.	Index of size of valleys.	Number of valleys inhabited by <i>hyalina</i> to the extent of—					Average valley collection.
		0	0 to 1 per cent.	1 to 2 per cent.	2 to 5 per cent.	5 per cent and over.	
Northern quadrant.....	I	..	..	..	..	2	815
	II	..	..	1	3	..	725
	III	..	2	1	1	..	383
Western quadrant.....	I	..	1	..	..	..	756
	II	..	1	..	1	..	408
	III	3	..	2	..	..	457
	IV	..	..	1	1	..	697
Southern quadrant.....	I	1	3	..	..	..	450
	II	2	3	1	1	..	422
	III	..	..	..	..	..	..
	IV	3	2	2	1	1	238
Eastern quadrant.....	I	..	..	..	..	..	..
	II	..	..	1	2	..	383
	III	..	3	1	..	..	429
	IV	2	..	..	1	..	262
Tahiti nui.....		11	15	10	11	3	437

TABLE 11.—Percentage of *hyalina* in relation to size and location of valleys. Tahiti. Summaries.

	No. of valleys.	Number of valleys inhabited by <i>hyalina</i> to the extent of—			Average valley collection.
		0	0 to 2 per cent.	2 per cent and over.	
Index of size of valleys:					
I.....	7	1	4	2	599
II.....	16	2	7	7	489
III.....	13	3	9	1	425
IV.....	14	5	5	4	309
Region:					
Northern quadrant.....	10	..	4	6	606
Western quadrant.....	10	3	5	2	525
Southern quadrant.....	20	6	11	3	345
Eastern quadrant.....	10	2	5	3	365
Tahiti nui.....	50	11	25	14	437

On the basis of the foregoing facts, we are led to ask whether the abundance or scarcity of *hyalina* might be related to or dependent upon distinctive ecological characteristics of the major quadrants of Tahiti nui and of different valleys located in these quadrants. To answer this question we may tabulate the percentage frequencies of this species in correlation with the size-indices of the several valleys in each major sector, as in tables 10 and 11, where the data are given in full and are

also summarized in a condensed form, so as to bring out more clearly any existing relation between an ecological character and a general degree of relative abundance. Two conclusions are warranted by the facts as given. The first is that the drier northern quadrant is most favorable for *hyalina*, because no valley which bears any snails at all is devoid of this form, while in 6 of the 10 valleys *hyalina* forms more than 2 per cent of the *Partula* population. The western sector is next in salubrity and is followed by the relatively moist eastern section. The wettest series of southern valleys proves to be the least favorable, for only 3 out of 20 valleys have more than 2 per cent of this species in their snail population.

The second conclusion is that the *larger* and *drier* valleys are more favorable than smaller elements with a higher degree of humidity. For example, in the northern quadrant the great valleys of Fautaua and Papenoo have the highest percentage of *hyalina*, 11 and 7 per cent respectively; the valleys of the next order (Ahonu, Tuauru, Pirai, and Tipaerui) average nearly 3 per cent (2.98), while the four tertiary valleys of the list average only 1 per cent, a figure that is brought up by Hamuta, which, possibly, is influenced by its close proximity to Fautaua.

In brief, the drier localities appear generally to be more favorable for the species than other regions. This result is of much importance in connection with later discussions of *hyalina* as it exists in the Cook and Austral Islands.

The facts, however, do not warrant the assumption that the relation of this species to certain environmental conditions is fixed and invariable. Many discordant cases appear from the full table (table 9), and some of these have been already specified. We are justified in stating that high degrees of general humidity are on the whole unfavorable to the species, but the exceptions are sufficiently numerous to demand a qualification of this assertion. It must be recognized that the vigorous and numerous colonies which exist in small valleys like Otuna, in the heart of an unfavorable region, must differ constitutionally from the generality of the species that are not so able to withstand adverse conditions. Hence, the conclusion warranted by the whole series of facts relating to the distribution of colonies of *hyalina* that vary in numerical abundance is as follows: *The members of this species vary constitutionally in diverse localities so as to possess different degrees of ability or disability to meet the particular conditions obtaining in such diverse localities.* Thus the observed relations are due primarily to ultimate factors of a *constitutional* and *congenital* nature, and not to external conditions alone.

#### THE SHELL OF PARTULA HYALINA AND ITS VARIATION—TAHITI.

Passing now to the statistical study of the structural characters exhibited by the shell of this species, we come to a more direct analysis of the problems of distribution and evolution, to which indeed the foregoing discussion of numerical distribution has been introductory, though no less significant in its result. We may now deal with the morphological peculiarities of the individuals which make up the colonies found in the various valleys, in order to ascertain whether local variation occurs; and, if so, whether this can or can not be related to environmental differences as causal factors.

The shell of *hyalina* has been described as practically invariable, not only throughout Tahiti but also in the whole field of its occurrence, which includes certain islands of the distant Cook and Austral Groups. Garrett calls particular attention to this uniformity as a remarkable feature of the distribution of this species, pointing to the diverse geological features of the elevated coral-limestone islands of the Cook Group as contrasted with the volcanic character of Tahiti. Yet, somewhat inconsistently, he also speaks of minor variations among *hyalina* such as "would be due to differences in food and station," thus attributing a high causal value to environmental circumstances.

The material for the present study of variation in the measured characters of the shell consists of 463 adult specimens, out of the entire number of 589. On account of their fragile nature, many shells are broken at the time of collection or transportation, so that all are not available for statistical treatment. The perfect shells have been examined and compared, valley by valley and quadrant by quadrant, on the basis of all of the seven characters specified in the introductory section. The embryonic contents of nearly the entire series have been taken into account also. But it must be plainly recognized that the several colonies of this species do not always comprise enough individuals to make a statistical analysis significant; were there as many specimens as in the case of *P. otaheitana*, we might compare the colonies valley by valley with entire confidence in the figures. In only a few cases do the numbers at hand rise above a score. Hence it has seemed best to proceed from a general to a more particular statistical description of the shells of this species, taking into account in the latter case only a few characteristic valleys situated in the several ecological and geographical divisions of Tahiti.

TABLE 12.—*Partula hyalina*. Tahiti. General statistical description of 463 adult shells.

Character.	Range.	Mode.	Mean value.	Standard deviation.
Shell:				
Length, mm. ....	12.6 to 17.7	15.35	15.3098 ± .0245	0.7802 ± .0171
Width, mm. ....	7.7 10.1	8.70	8.7415 ± .0130	0.4156 ± .0091
Proportions, p. ct....	51.5 63.5	57.50	57.0227 ± .0650	2.0687 ± .0453
Aperture:				
Length, mm. ....	7.4 to 10.2	8.80	8.9024 ± .0150	0.4782 ± .0105
Width, mm. ....	5.4 7.6	6.40	6.5028 ± .0121	0.3852 ± .0084
Proportions, p. ct....	65.5 82.5	72.50	72.9514 ± .0723	2.3034 ± .0504
Length aperture ÷ length shell, propor- tions, p. ct. ....	52.5 66.5	57.50	58.0378 ± .0518	1.6493 ± .0361

Taking all of the available material of this species as it exists in Tahiti, the data relating to the seven essential characters (table 12) provide an accurate quantitative description of the shell formed by this animal. Moreover, figures 1 to 10, plate 20, show certain characteristic examples of the species. Specifically the shell of figure 1 is the shortest specimen, taken in Tautira Valley; in spite of its small size the animal was nevertheless an adult, for its brood-pouch contained several young. The next shell, figure 2, is almost equally abbreviated; it is the broadest of the

entire island population, and it also was certainly an adult, as the animal contained eggs and embryos. The longest shell, figure 3, is from Paraura Valley. The most slender, figure 4, is from Tipaerui. Figures 5 and 6 show the average shell as regards the proportionate measures; they are from Fautaua Valley. The shells of a thinner texture are illustrated by an example from Haavini Valley, shown in figure 7. Quite infrequently abnormal individuals are found where an injury has been repaired, as in a shell from Papenoo Valley, figure 8. The obliquity of the plane of the aperture is illustrated in figure 9. Finally, an adolescent individual devoid of the last whorl and flaring lip is shown in figure 10.

TABLE 13.—*Partula hyalina*. Tahiti. Detailed statistical analysis of shells of major regions.

MEAN VALUE.								
Region.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.	
Quadrant:		mm.	mm.	p. ct.	mm.	mm.	p. ct.	p. ct.
North.....	212	15.2173 ± .0340	8.7734 ± .0198	57.5707 ± .0872	8.8566 ± .0223	6.4783 ± .0183	73.1179 ± .0998	58.1321 ± .0877
West.....	60	15.0850 ± .0612	8.6367 ± .0400	57.2167 ± .2050	8.7200 ± .0490	6.5600 ± .0368	74.7667 ± .1921	57.7166 ± .1706
South.....	51	15.4382 ± .0776	8.7235 ± .0348	56.5000 ± .1852	8.9647 ± .0372	6.5255 ± .0372	72.8529 ± .2472	57.9117 ± .1901
East.....	49	15.3806 ± .0785	8.6388 ± .0388	56.1122 ± .1774	8.9265 ± .0369	6.4122 ± .0306	71.7245 ± .1287	57.9286 ± .1497
Tahiti nui...	372	15.2452 ± .0267	8.7269 ± .0149	57.1747 ± .0716	8.8586 ± .0168	6.4860 ± .0138	73.1639 ± .0836	58.0081 ± .0661
Taiarapu...	91	15.5742 ± .0503	8.8011 ± .0256	56.4011 ± .1447	9.0813 ± .0306	6.5714 ± .0243	72.0824 ± .1207	58.1593 ± .1077
Whole island.	463	15.3098 ± .0245	8.7415 ± .0130	57.0227 ± .0650	8.9024 ± .0150	6.5028 ± .0121	72.9514 ± .0723	58.0378 ± .0518
STANDARD DEVIATION.								
Quadrant:								
North.....	212	0.7349 ± .0241	0.4276 ± .0140	1.8833 ± .0618	0.4823 ± .0158	0.3949 ± .0129	2.1566 ± .0707	1.8949 ± .0621
West.....	60	.7023 ± .0433	.4597 ± .0283	2.3529 ± .1449	.5623 ± .0346	.4223 ± .0260	2.2050 ± .1358	1.9586 ± .1206
South.....	51	.8216 ± .0549	.3686 ± .0246	1.9603 ± .1309	.3934 ± .0263	.3939 ± .0263	2.6183 ± .1749	2.0114 ± .1344
East.....	49	.8136 ± .0555	.4024 ± .0274	1.8385 ± .1254	.3826 ± .0260	.3166 ± .0216	1.8872 ± .1287	1.5518 ± .1058
Tahiti nui...	372	.7633 ± .0188	.4264 ± .0105	2.0462 ± .0505	.4789 ± .0118	.3931 ± .0097	2.3900 ± .0590	1.8885 ± .0466
Taiarapu...	91	.7098 ± .0355	.3623 ± .0181	2.0437 ± .1022	.4317 ± .0216	.3426 ± .0171	1.7043 ± .0852	1.5207 ± .0760
Whole island.	463	.7802 ± .0171	.4156 ± .0091	2.0687 ± .0453	.4782 ± .0105	.3852 ± .0084	2.3034 ± .0504	1.6493 ± .0361

The next task is to compare the snails of different sections of the whole island. It appears from the figures of table 13 that the shells from Tahiti nui, as compared with those of Taiarapu, are shorter, narrower, and stouter; their apertures are also shorter, narrower, and more broadly oval; finally, the aperture is somewhat shorter with reference to the total shell length. Thus there are distinct morphological differences between the shells of the two main divisions of Tahiti as a whole.

Furthermore, the shells of different quadrants possess diverse characteristics. For example, those of the headquarters region in the north are somewhat shorter than the southern shells, and far shorter than those of Taiarapu. They are also broader than the southern forms, and only slightly narrower than the individuals from Taiarapu. In proportionate measures, however, these shells are much stouter than the southern and peninsula classes.

Finally, we may compare certain colonies which comprise enough individuals to render the statistical constants of their tabulated characters significant to some

degree, although implicit reliance upon their final value must be withheld. Table 14 gives the figures for five valleys of the northern quadrant, four of the west, two of the southern region, two of the east, and four of Tairapu. Were the individuals of the several colonies sufficiently numerous, it would be worth while to make a close comparison, valley by valley, of the whole population, a task which will be undertaken for other species of Tahiti. Under the circumstances, however, only a few of the general results may be derived from the recorded numerical data. In each quadrant some of the colonies vary in one direction in a given character, while others depart in the opposite way for the regional average, as defined in the previous table. The shells of Tairapu are by far the most illustrative of this point; those of Vavii

TABLE 14.—*Partula hyalina*. Tahiti. Statistical description of representative colonies.

MEAN VALUE.								
Valley.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.	
		<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>p. ct.</i>
Papenoo....	34	14.7500±.0906	8.3824±.0446	56.7353±.1841	8.4588±.0545	6.1294±.0400	72.3824±.2409	57.3235±.1973
Tuauru....	12	14.9500±.0993	8.6000±.0539	57.5833±.3415	8.7167±.0919	6.4166±.0719	73.9166±.3022	58.0833±.4799
Pirai.....	37	15.2527±.0679	8.9000±.0455	58.0676±.2165	8.9892±.0446	6.5622±.0421	72.9054±.2284	58.8243±.2158
Fautaua....	93	15.2436±.0508	8.8720±.0273	58.1344±.1170	8.8710±.0312	6.5376±.0249	73.6505±.1465	58.2312±.1240
Tipaerui....	16	15.5000±.1012	8.6250±.0570	55.6250±.3090	8.9500±.0768	6.4750±.0629	72.6250±.3090	57.2500±.3501
Taapuna....	12	15.4500±.1774	8.6334±.1009	59.1666±.3309	8.9500±.1283	6.5833±.0999	73.1666±.2295	57.8333±.3309
Maruapoo..	9	15.1167±.1004	8.8333±.0948	58.0555±.6280	8.8222±.0820	6.5777±.0747	74.3888±.6740	57.8333±.3821
Atehi.....	11	15.3227±.1570	8.8636±.1108	58.0454±.6093	9.0000±.1451	6.8909±.0955	76.5909±.5939	58.9545±.5229
Aoua.....	19	14.6711±.0766	8.4369±.0532	57.3947±.2063	8.4211±.0530	6.3579±.0444	75.2895±.2909	57.4474±.1625
Otuna.....	18	15.0934±.1209	8.5778±.0562	56.9445±.2815	8.9777±.0542	6.5888±.0631	73.1666±.3555	59.1666±.2702
Tenaire....	7	15.9071±.2020	8.9571±.1009	56.0714±.2303	8.9714±.0961	6.6286±.0635	73.5000±.1927	56.2143±.3257
Paraura....	21	15.5786±.1218	8.6905±.0645	55.5475±.2337	8.9619±.0486	6.4286±.0355	71.4524±.3029	57.5000±.2081
Faarumai...	10	14.9600±.1181	8.4400±.0662	56.2000±.3171	8.6400±.0533	6.3800±.0554	71.5000±.3016	57.8000±.1919
Tehoro....	9	15.9166±.1572	8.7000±.0734	54.6112±.1657	9.1333±.0948	6.6222±.0651	71.9445±.2620	57.1667±.3294
Haavini....	20	15.2150±.0875	8.7900±.0387	57.6500±.2624	9.0000±.0477	6.5400±.0383	72.5500±.2545	58.9500±.2210
Tautira....	17	14.8735±.1226	8.5588±.0535	57.6176±.3168	8.9882±.0748	6.3177±.0573	72.1471±.1678	58.9118±.2513
Vavii.....	21	16.0500±.0844	9.0047±.0432	55.8810±.3314	9.3333±.0605	6.7047±.0564	72.1191±.2153	57.9285±.1849
STANDARD DEVIATION.								
Papenoo....	34	0.7836±.0640	0.3854±.0315	1.5915±.1302	0.4716±.0385	0.3460±.0283	2.0830±.1703	1.7058±.1395
Tuauru....	12	.5099±.0702	.2769±.0381	1.7539±.2415	.4723±.0650	.3693±.0508	1.5524±.2137	2.4650±.3393
Pirai.....	37	.6122±.0480	.4106±.0322	1.9526±.1531	.4025±.0315	.3801±.0298	2.0597±.1615	1.9459±.1526
Fautaua....	93	.7264±.0359	.3909±.0193	1.6728±.0827	.4463±.0220	.3568±.0176	2.0942±.1036	1.7728±.0877
Tipaerui....	16	.6000±.0715	.3382±.0403	1.8328±.2185	.4555±.0543	.3733±.0445	1.8328±.2185	2.0766±.2475
Taapuna....	12	.9110±.1254	.5185±.0713	1.6996±.2340	.6589±.0907	.5129±.0706	1.1785±.1623	1.6996±.2340
Maruapoo..	9	.4467±.0710	.4216±.0670	2.7933±.4440	.3646±.0580	.3325±.0528	2.9979±.4766	1.6996±.2702
Atehi.....	11	.7723±.1110	.5449±.0783	2.9959±.4308	.7135±.1026	.4699±.0675	2.9203±.4199	2.5713±.3697
Aoua.....	19	.4948±.0541	.3437±.0376	1.3336±.1459	.3428±.0375	.2871±.0314	1.8800±.2057	1.0500±.1149
Otuna.....	18	.7542±.0855	.3536±.0397	1.7708±.1990	.4211±.0382	.3970±.0446	2.2361±.2514	1.6996±.1910
Tenaire....	7	.7926±.1428	.3959±.0713	0.9034±.1628	.3769±.0679	.2490±.0449	.7559±.1362	1.2777±.2303
Paraura....	21	.8276±.0861	.4385±.0456	1.5878±.1652	.3302±.0344	.2413±.0251	2.0581±.2142	1.4142±.1471
Faarumai...	10	.5539±.0835	.3105±.0468	1.4866±.2242	.2498±.0377	.2600±.0392	1.4142±.2133	.9000±.1357
Tehoro....	9	.6992±.1111	.3266±.0519	.7372±.1172	.4216±.0670	.2897±.0460	1.1653±.1852	1.0541±.2329
Haavini....	20	.5803±.0619	.2567±.0274	1.7399±.1855	.3162±.0337	.2538±.0271	1.6874±.1799	1.4654±.1563
Tautira....	17	.7495±.0867	.3273±.0378	1.9367±.2240	.4574±.0529	.3502±.0405	1.0256±.1186	1.5361±.1777
Vavii.....	21	.5732±.0597	.2936±.0305	2.2514±.2343	.4109±.0428	.3836±.0399	1.4631±.1522	1.2563±.1307



constitute the longest group of the whole island, while in Tautira they are almost the shortest collectively. The proportionate measurements vary quite as much as the absolute dimensions, and independently of the latter to some degree. In general, *shortness* and *stoutness* of the whole shell go together, but the Tipaerui shells, as compared with those of Fautaua, are far more slender, even though they are shorter as a group. Each colony, therefore, seems to be more or less peculiar in its own way—in an absolute dimension, in a proportionate characteristic, and in its particular combination of all seven determinations.

#### INTERPRETATION OF THE FACTS.

The observations recorded in the foregoing sections render it possible to effect a partial solution of the major problem under consideration—the problem, namely, which deals with the causal value of the “environment” in producing varietal modifications wherever these can be demonstrated. We have seen that, in Tahiti, *Partula hyalina* occurs in secluded colonies living in more or less rigidly isolated valleys, in practically all of the administrative and geographic districts of the island. But the species is far from uniform, either in its frequency or in the structural characteristics of its shell. Must we conclude that the observed differences owe their origin to diverse environmental conditions obtaining in different areas of the island? In my opinion, the question should be answered in the negative.

In the first place, it is impossible to find geological, meteorological, or hetero-generic biological conditions which vary essentially around the island. The plants upon which the animals are found occur everywhere, although their relative abundance is by no means the same in widely separated or even in neighboring and parallel valleys. As the snails eat decaying vegetation, it is natural that no correlation can be demonstrated between the prevalence in a given valley of a certain type of habit-plant, like the *Colocasia*, and certain characters of *hyalina* in that valley, as regards either colonial abundance or shell structure. The facts demonstrate that *hyalina* occurs more numerously in the drier northern district and in the larger valleys of this and other quadrants. It is also true that the shells of the northern drier section are different morphologically from those of colonies in the wet regions. But the facts also show that the relations mentioned are not invariable by any means; if they were, we might be forced to conclude that high and low degrees of moisture acted as direct causal factors for the development of peculiar varietal features.

The conclusion which appears more just is that the morphological differences observed are due to spontaneous congenital causes that remain unknown in themselves, but whose effects are produced quite independently of the external conditions; to this statement we may add that even the greater abundance of a colony found in a drier valley may also be indicative of a congenital variation of a favorable nature. With regard to the latter point, it may be recalled that in such a valley as Otuna, situated in the wet district, *hyalina* forms more than 5 per cent of the population as represented by 382 adult snails; in Maruia, the nearest valley on the west of Otuna, *hyalina* does not occur at all. Unless this indicates a congenital vigor of the snails of the Otuna colony, making them fit to meet circumstances that on the whole are





A. The western end of Papeete, and Tipaerui Valley. The high ridge in profile forms the main boundary between the northern and western sectors. The dry sector to the east (left) of Tipaerui is free from *Partulae*.



B. Papehue Valley, an element of the third order of size, looking inland from near its mouth.



unfavorable for the species, the facts are unintelligible. To this case could be added many of the converse nature where, in the favorable region of the northern drier quadrant, *hyalina* colonies are numerically weak. If, then, the relation between abundance and a particular environmental condition like greater dryness or wetness is not invariable, the ultimate and primary causes of colonial vigor or weakness are to be sought in constitutional characteristics of the snails themselves.

By a parity of reasoning, the diverse structural characters of the shells of *hyalina*, particularly in proportional measures, must be referred ultimately to congenital differences in the animals, and not to the direct operation of differences in moisture or in supplies of food. It is theoretically conceivable that in a given valley the snails might feed more and consequently grow to a larger size, while in another region they might feed less and remain stunted in stature. But the facts rule out any such hypothesis. More rain and wetter forest render the snails active, so that they feed during more hours of the day in a moist region than in a large dry valley. Yet the shells of the drier north, though shorter, are wider and stouter than those of the wet southern quadrant. The shells of Tairapu as a whole, a region far wetter than Tahiti nui, are longer and wider but less stout as compared with those from the larger part of the entire island. Taking all the facts into account, we can only conclude that congenital factors are ultimate for the establishment of the varying colonial types observed in different valleys.

#### FECUNDITY.

Like all other species of the genus, *Partula hyalina* is viviparous. The shell is about 3 mm. in diameter when the young animal leaves the brood-pouch of the parent and shifts for itself. The complete study of *hyalina* must deal with certain aspects of the relations between young and parents, although these relations are of far greater interest in other cases, like *otaheitana* and *nodosa*, where definite color varieties occur within the limits of the species, and where both sinistral and dextral shells are produced in one and the same species and variety.

When the brood-pouch of a gravid individual is opened, the developing young are revealed, each inclosed within a tough egg-shell which, in this species and in one or two others (such as *P. clara*), is invariably transparent. The egg at the time of its fertilization is extremely minute; as the embryo grows, it feeds upon the albumen around it and gradually comes to fill the inclosing egg-shell.

The number of eggs and of embryonic young varies in individuals taken at any one time, the highest being 9. They are arranged in order with the most advanced nearest to the birth aperture, that is, in a sequence according to age. In only a single instance out of the 250 records of gravid *hyalina* adults was there any departure from this order, in a case where the formula was as follows: y, y, y, egg, y, y, egg—the last egg being most internal. Such anachronisms are found with equal infrequency in the other species of this island.

The statistical data relating to the fecundity of *hyalina* in my collections are presented in table 15. It is obvious that a given individual does not breed continuously throughout its productive period, for only 64.9 per cent contain embryonic

young at any one time. The average number of young and eggs is 3.75 for each bearing adult and 2.44 for each individual of the entire adult population of nearly 400.

The same table shows that there is no well-defined season for breeding in the case of this species, for the data of 1906 are substantially the same as those relating to 1907, 1908, and 1909, although collections were made during the last of the wet season in the first-mentioned year, and during the alternating period of less rainfall during the last-named. From the facts relating to *P. otaheitana*, presented in a subsequent section, it is certain that in that form there is greater reproductive activity at the advent of the wet season. Apparently *hyalina* does not agree with *otaheitana* and other species in this respect.

The data may be rearranged so as to bring out any differences in fecundity that may exist in colonies of diverse regions (table 15). The figures show that the rate of multiplication is not the same in the several major divisions of Tahiti, nor is it uniform in any series of contiguous valleys lying in one ecological section, as a more detailed comparison shows. In brief, the reproductive phenomena under consideration vary like numerical abundance and structural characters, without reference to any external circumstances that can be discerned. Within the limitation of its specific characters, each colony constitutes an independent type.

TABLE 15.—*Partula hyalina*. Tahiti. Statistics of fecundity.

ANNUAL OBSERVATIONS.							
Year of observation.	No. of stations.	No. of records.	No. of gravid.	Per cent gravid.	No. of young and eggs.	Average for gravid.	Average for all.
1906.....	16	143	88	61.5	330	3.75	2.30
1907.....	31	202	137	67.8	519	3.78	2.56
1908.....	6	24	14	58.3	60	4.28	2.50
1909.....	11	28	19	67.8	60	3.15	2.14
All years.....	64	397	258	64.9	969	3.75	2.44
REGIONAL CLASSIFICATION.							
Quadrant:							
North.....	21	202	129	63.8	464	3.59	2.29
West.....	7	47	26	55.3	72	2.76	1.53
South.....	17	46	27	58.6	107	3.96	2.32
East.....	8	44	32	72.7	136	4.25	3.54
Taiarapu.....	11	58	44	75.8	190	4.31	3.27
Whole island....	64	397	258	64.9	969	3.75	2.44

#### FECUNDITY AND ELIMINATION.

A question of much biological interest is concerned with the possibility of a relation between the high average fecundity of *hyalina* and the process of elimination by which the numbers of new-born young become reduced. We may justly assume that the species under consideration has attained a condition of approximate equilibrium as regards its numerical abundance, so far as this depends upon the incident action of external agencies. We may also regard the collections as representative of the whole island-population of *hyalina*. These collections comprise



B. Mangaia, one of the Cook or Hervey Islands,---an uplifted atoll.



A. The region of Otuna, Opiriroa, and Tearatapu Valleys (from left to right) showing the thicker vegetation of the lower levels in the wetter southern quadrant. (Photo. Bopp du Pont).



three distinct classes of individuals, namely, the embryonic, the adolescent, and the adult snails. The first-named constitute an arbitrarily defined generation destined to enter upon a free and independent existence at a later time and to become reduced in numbers through the inability of some individuals to meet successfully the conditions of adolescence and maturity. The second class of adolescents also constitutes an arbitrarily defined generation produced earlier, and also fated to be decimated before all its members can reach reproductive maturity. The adults, finally, form a third generation whose members are survivors of a still longer period of natural elimination. In the present material the third class is made up of the actual parents of the first class; but if the assumption is correct that the three specified groups are representative of an equilibrated population, the relationship in question is not a disturbing factor.

In order to obtain a measure of the severity of elimination, it is necessary only to compare the known number of adults with the known number of embryonic young, for although the problem of the relative numbers of the post-embryonic but immature individuals is interesting, it can be disregarded in this connection.

Judging from the actual facts at hand, 969 eggs and young are to replace 397 adults. The exact number of young per adult snail is 2.44, as noted in the preceding section; or, in other words, 2 adults of one generation bring forth about 5 young of a succeeding generation. But unless the species is rapidly increasing in numbers—for which there is no evidence—then only 2 of the 5 new-born snails will survive to assume full adult form and ability, and 3 are destined to be eliminated through constitutional incapacity or from the effects of adverse external circumstances, such as prolonged drought, or from the attacks of other organisms.

#### PARTULA HYALINA FROM THE COOK ISLANDS.

The Cook Islands are seven in number and form a group centering about a point  $21^{\circ}$  S. lat., and  $158^{\circ}$  W. long. They are thus about 500 miles to the WSW. of Tahiti and the same distance to the WNW. of Rurutu in the Austral Group. The principal islands are Rarotonga, Mangaia, Moki, Aitutaki, and Atiu. I personally obtained *hyalina* on Mangaia and Moki, while search was futile in Aitutaki and Rarotonga, although the last-named is reported to be inhabited by this species; I believe, however, that the record is erroneous.

Rarotonga is the largest member of the group, and the only one that consists of volcanic rock. In its general structure it closely resembles Tahiti and other "high" islands, in so far as the whole mass is furrowed by deeply cut valleys, bearing vegetation essentially similar to that of Tahitian localities. In certain sections, however, cultivation has extended so greatly as to reduce materially the territory occupied by primitive forests in the floors of the valleys, even at some distance inward from the coast.

Mangaia is an uplifted mass of coral limestone, which still displays the structure of an atoll (plate 16*b*.) A dry circular valley with high and abrupt walls occupies the interior, which was undoubtedly the lagoon of the island during an earlier

period in its history. Moki (sometimes spelled Mauke) is similar in structure, but the central area is not so deeply depressed as in Mangaia, nor are there any cliffs surrounding the now dried lagoon. Aitutaki is likewise an uplifted limestone mass.

Garrett visited Rarotonga, Mangaia, Atiu, and Aitutaki, and reported *hyalina* from Mangaia only. His thorough exploration of other islands would certainly enable him to discover the species if it occurred. In Voy's collection, now in the Philadelphia Academy of Natural Sciences, there are some *hyalina* shells labeled Rarotonga. In view of Garrett's statements, and on account of my own inability to find *hyalina* in a particularly favorable valley in the island, I conclude that Voy's shells were obtained from natives who had brought them to Rarotonga from another place.

My own material from Mangaia consists of "dead shells" taken from the ground near the cliffs bordering the lagoon-like valley. Only here, where the orange and other trees grow thickly, is there a situation sufficiently moist and shaded where *hyalina* can live. The absence of living examples must be attributed to the excessively dry weather of the previous weeks that had driven the animals to deep shelter. In Moki living individuals were taken in dense *Pandanus* thickets a mile inland, at an altitude of 150 feet, aneroid barometer. Here and in two other forest localities dead shells were found, but no living specimens were seen at the latter places.

Characteristic Cook Island shells are shown in figures 11 to 13, plate 20. Figure 11 shows a small example from Moki, and figure 12 presents a large specimen from the same island. The shell of figure 13 is an average specimen from Mangaia.

The statistics relating to these collections are given in tables 16 and 17. The conclusions drawn from the tabulated data are the following:

(1) The adult shells of *hyalina* from Mangaia are *longer*, *wider*, and *stouter* than those of Moki; their apertures are also *longer* and *wider*, but *more narrowly oval*; the aperture is relatively *longer* in proportion to the total length of the shell. These conclusions are based upon a comparison of the dead shells from the two localities in question. From inspection it is clear that weathering of a dead shell reduces the apex more rapidly than the lower whorls or the margin of the aperture, but in the above comparisons such changes can be justly ignored.

(2) The shells of living *hyalina* from Moki are larger on the whole than the dead examples from the same locality; the differences observed serve to indicate the amount of the change produced by the weathering of the apex and margin of the aperture.

(3) Combining the above results, it would appear that living snails from Mangaia would undoubtedly be correspondingly larger than the dead shells; and if the available material were more abundant it would be profitable to determine the probable values of the several characteristics of the "living" shells from that island for comparison with forms from other islands.

(4) Comparing the characteristics of adult shells from Moki with the whole population of Tahiti, it appears that the former are significantly different in several characters. The precise differences with their probable errors are given in table 17.



While the matter of length is unimportant, the diversity in width, and therefore in shell proportion, is decidedly indicative of real island differentia. As regards the aperture, no profound differences are found, except in the case of its length as compared with that of the whole shell. In all seven characters the Moki shells are less variable, and significantly so in four cases.

TABLE 16.—*Partula hyalina*. Cook Islands. Statistical description.

MEAN VALUE.								
Locality.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.	
		mm.	mm.	p. ct.	mm.	mm.	p. ct.	p. ct.
Mangaia, dead..	46	15.9174±.0814	8.9565±.0295	56.1087±.1826	9.3043±.0304	6.6667±.0933	71.5667±.2221	58.4783±.1766
Moki, dead.....	38	14.9553±.0817	8.3789±.0390	55.8947±.1870	8.5621±.0440	6.2842±.0331	73.2632±.2405	57.1053±.1637
Moki, living....	15	15.4700±.0970	8.4067±.0400	54.3667±.2192	8.8667±.0550	6.4533±.0371	72.8333±.2962	57.2323±.2155
Moki, all.....	53	15.1001±.0701	8.3868±.0289	55.4623±.1608	8.6340±.0377	6.3321±.0269	73.1415±.1853	57.1415±.1323
STANDARD DEVIATION.								
Mangaia, dead..	46	0.8185±.0814	0.2968±.0209	1.8353±.1290	0.3056±.0215	0.9261±.0658	2.2060±.1568	1.7753±.1248
Moki, dead.....	38	.7476±.0579	.3562±.0276	1.7097±.1323	.4023±.0311	.3030±.0235	2.1983±.1701	1.4963±.1158
Moki, living....	15	.5564±.0686	.2294±.0283	1.2578±.1551	.3155±.0389	.2126±.0262	1.6996±.2096	1.2364±.1524
Moki, all.....	53	.7575±.0496	.3120±.0204	1.7370±.1138	.4069±.0266	.2906±.0190	2.0008±.1311	1.4287±.0936

TABLE 17.—*Partula hyalina*. "Living" shells of Moki as compared with those of Tahiti.

Character.	Mean value.	Standard deviation.
Shell, length, mm.....	[+0.1602±.1000]	[−0.1238±.0707]
width, mm.....	−.4348±.0420	−.1862±.0297
proportions, per cent.....	−2.6560±.2286	−.7109±.1615
Aperture, length, mm.....	[−.0357±.0570]	−.1627±.0402
width, mm.....	[−.0495±.0390]	−.1726±.0278
proportions, per cent.....	[−.1181±.3048]	[−.6038±.2155]
Length aperture ÷ length shell, proportions, per cent.	−0.8055±.2155	[−.4129±.1566]

Of the 15 adult *hyalina* taken on Moki, 14 proved to be gravid (93.3 per cent). It was still more surprising to find that these parents yielded 31 eggs and 72 young, giving a total of 103. Thus the average number of embryonic individuals is 7.35 for gravid adults and 6.86 for the whole series. These figures indicate a much higher degree of fecundity than in the case of Tahitian snails and, if we should treat them as we did the figures in the case of the latter, it would seem that elimination is far more searching in its effects on colonies living on relatively low islands composed of coral limestone. Only 1 in 7 new-born young is able to reach reproductive maturity. However, we can not place the same reliance upon these figures as upon the fuller data relating to the snails of Tahiti.

GENERAL DISCUSSION OF THE DISTRIBUTION OF *PARTULA* *HYALINA*.

On the basis of the details and summaries presented in the foregoing pages, we may now undertake a broader discussion of the wide geographical range of *Partula hyalina*, which renders this species unique in its genus. The primary fact is that one and the same species exists in far-separated islands belonging to three distinct groups, and that these islands differ also in geological structure and origin. Tahiti is a veritable classic as an example of the so-called "high" volcanic islands. In the Austral or Tubuai Group, Rurutu (Oheatara of Broderip, Oheatoroa of Cook) is about 8 miles in circumference and rises to a height of 1,500 feet; the lowermost level up to an altitude of about 100 feet is composed of coral limestone exposed by the uplift of the whole land-mass. This island lies more than 250 miles from the nearest point of Tahiti, from which it is almost due south. Tubuai is another island of the group, 100 miles southeast of Rurutu, and this also bears *hyalina*, as asserted by Garrett (Proc. Acad. Nat. Sci. Phila., 1879), who indeed regarded this group as the "metropolis" of the species. The geographical features of the Cook Group have been described in the foregoing section.

The snails under discussion existing in these three groups obviously belong to the same species, even though the shells from the Cook Islands prove to be characteristically different in certain details from Society Island shells, when examined by precise statistical methods. We are not confronted by a case of parallel or convergent evolution, because it is not probable that convergence would bring about a double or triple development of colonies possessing so many identical qualities in texture and form of the shell, in the obliquity and shape of the aperture, and in the transparency of the embryonic membrane. The differences noted are quantitative within the qualitative limits of the common characteristics, and there is but one natural species of *P. hyalina*.

While the occurrence of one identical species in three distinct groups of widely separated islands is sufficiently remarkable in itself, it is still more surprising to find that it exists only in certain members of each of these three groups. Moorea lies only about 12 miles from Tahiti, but it is quite as free from *hyalina* as Raiatea and the more distant members of the Society Group. The absence of this type from Atiu and Aitutaki is not so unexpected; for these islands are flat, uplifted atolls, devoid of the dense jungle overshadowed by high, precipitous mountain ridges which are such important environmental elements in Tahiti and its kind. Nevertheless, Mangaia and Moki are like Aitutaki, yet they bear *hyalina*; while Rarotonga, which is a high island, seems to be at least doubtful as a habitat for this species.

There are two interpretations of these facts and only two: (1) *hyalina* may have been transported from its original locality in one of these groups to the other two, by human agency; (2) it may be an ancient species which had reached its present specific condition before the old and continuous mountain ranges had been isolated by subsidence so as to become the present series of unsubmerged peaks which constitute the different groups of volcanic islands. We may consider the facts *pro* and *con* in each case.

(1) It is well established by the comparative study of Polynesian tradition that the Cook and Austral Islands were peopled from the Society Group. But whichever one of the two groups was the stepping-stone from Tahiti to the other, the fact remains that numerous voyages were made by the natives in their outrigger canoes to and fro among these three groups. The traditional history of the natives is full of accounts telling of military expeditions for conquest and pillage. In one case in my knowledge, the tale recites the hardships of natives sent from Tahiti by a priest during a time of famine, to procure food from "an island in the South," which they found and which is now identified with one of the Austral Group. As the people of the flotilla must needs have taken food-supplies, it is conceivable that snails of this species, sealed up upon a cluster of plantains, might have been carried alive to a new locality, where they may have established their kind.

Militating against this explanation, however, is the absence of *hyalina* from Moorea and other islands near Tahiti, and from Aitutaki, Atiu (and Rarotonga?), which are neighbors of Mangaia and Moki. The intercourses of natives belonging to different islands of one group must have been closer and more frequent than in the case of the three groups taken as units, on account of the numerous intermarriages and wars of which records exist. It is not probable, therefore, that *hyalina* would be carried to a far distant group in infrequent communication with headquarters when the species is absent from islands in close proximity that were visited more often. Latterly the development of modern methods of trade has greatly facilitated intercommunication among the islands of each of these groups, yet no case appears, either in Garrett's experience or in my own, where natives have transplanted a type from one island to another, even from Tahiti to Moorea or *vice versa*.

(2) The contention that *hyalina* is an ancient type remaining in certain of the peaks formerly belonging to a continuous land-mass, suggested also by Pilsbry, is involved with the doctrine of subsidence. It is firmly supported by the evidences relating to other species of *Partula*, considered beyond. Against this contention two considerations may be urged, the first of which is biological, while the second is geological in nature.

It may be argued that if *hyalina* was a widespread species before the present islands of the Society Group were isolated, this species ought to be found in some of the other elements besides Tahiti. It is true that the environmental conditions are the same in all the larger "high" islands of this group, at least in so far as their effects upon *hyalina* are concerned; this is clear from the occurrence of *hyalina* in drier and wetter and in higher and lower stations of Tahiti which find their counterparts in Moorea and other neighboring islands. If the second interpretation of the history of *hyalina* is correct, we must conclude that the species did exist at one time in what are now Moorea and Raiatea and the rest, but its colonial variation was such as to result in the extinction of the species in all of the islands except Tahiti. We have learned from the analysis presented in the foregoing sections that *hyalina* varies much in different valleys of Tahiti, in structural respects as well as in its innate vigor. Even if we should ignore those stations where the species are not found, and focus our attention on the positive data, it appears that in an

island inhabited by the species, some of the valley colonies are so low in vitality as to be in imminent danger of extinction. It is indicated as probable, therefore, that the former range of *hyalina* extended over the whole Society Group, and even so far as to include the high islands of the Austral and Cook Groups. The facts in the case of *Partula attenuata* are extremely significant in this connection, for that species lives in Raiatea as well as in Tahiti, but not in Huahine, Tahaa, or Moorea. It occurs only in the remotest and highest portions of the valleys, on the upper portions of trees quite different from the plantain and other nurse-plants. It can not be argued that a form with such habits could be introduced by human agency into Raiatea from Tahiti or *vice versa*; it must be a species which had a far wider distribution at a remote period, and which has disappeared everywhere save in the two islands specified.

The greater obstacle to the acceptance of the general interpretation with which we are dealing consists in the limestone character of Mangaia and Moki. These are uplifted atolls devoid of volcanic centers. According to the doctrine of subsidence, they are formed out of coral constructed about and above a volcanic cone, which has entirely withdrawn or has weathered away to a level below that of the sea. A subsequent uplift of the floor of the ocean has brought the limestone mass to its present position. If *hyalina* had existed upon the original mountainous island, the reduction of the land surface to sea-level would presumably have destroyed the environmental conditions under which the animals could live; if it could not have withstood the relatively dry atmosphere of a low atoll, it must have become extinct before the reverse geological process of upheaval had reestablished a higher region with dense vegetation and shade like that now occupied by the animals in Moki and Mangaia. Under such circumstances the present occurrence of *hyalina* in these places would therefore be due to human introduction.

In my opinion, however, it is not necessary to abandon the consistent view that the present colonies of *hyalina*, existing on widely separated islands of diverse geological nature, are the remnants of an ancient species with a former wide range in Polynesia. In discussing the facts in the case of Tahitian colonies, it was shown that *hyalina* thrives in the drier quadrant of the major element, in the wider and more open valleys of all quadrants, and in the less moist situations within the valley areas of its occurrence; as a species, it shows a marked tolerance of heat and drought. Hence it does not seem unreasonable to suppose that highly resistant individuals might survive the vicissitudes of existence during the geological transformations involved in the production of an uplifted limestone island like Mangaia and Moki.

In conclusion, then, *Partula hyalina* seems to be an old species specialized to such an extent that pigmentation has been completely lost. Subsequent alterations of its originally continuous territory, through which island groups and islands were isolated, led to its dispersal in separate island colonies on volcanic peaks. From nearly all of these it has disappeared, owing to an inherent lack of vigor in certain of its associations, while even in Tahiti, where it still exists, it has disappeared from some of the valleys for the same reason. The shells vary colonially in dimensions, in relative measures, and in their combinations of absolute and relative characters.

## CHAPTER IV.

### PARTULA CLARA Pease.

#### GENERAL CONSIDERATIONS.

Like *hyalina*, *Partula clara* is a well-separated species with a virtually unclouded taxonomic history. It occurs only in Tahiti; in its restriction to a single island it agrees with most of the other species of the genus, and stands in sharp contrast to *hyalina*. In addition to variations in size and shape, in different localities it also exhibits color variations of a striking nature. In brief, it presents many features of distribution that are similar to those offered by *hyalina*, while it adds to these certain other peculiarities of high significance.

Pease described *clara* in 1864 as follows:

“P(artula) T(esta) ovata, subelongata, tenui, subpellucida, vix nitida, anguste umbilicata; anfr. IV., tenuiter et regulariter transversim striatis plano-convexis; apertura ovata, subobliqua, edentata, labro plane incrassato; flavide cornea vel pallide castanea, strigis longitudinaliter variegata. Long. 16, diam. 10 mill. Var: Linea unica, vel lineis duabus tribusve cingulata.”

Carpenter, in commenting on the above description by Pease, says that “*clara* seems to be a variety of the form returned by Mr. Cuming as *P. hyalina* Brod.” and a similar confusion exists in the case of some of the specimens at the Smithsonian Institution, as noted also by E. A. Smith. With these exceptions, *clara* has always been recognized as a clear species, although an ally of *hyalina*. Among the characteristics that indicate this proximity are the somewhat thin and transparent texture of the shell, its delicate and almost microscopic surface sculpturing, the invariable dextral coil, the total absence of a pillar tooth, except in the shells of one valley, and the obliquity of the aperture.

By far the most important statement in the literature is Garrett's paragraph referring to *clara*. He says this is a “rare species confined to the *upper portions* of the valleys in the southwest part of Tahiti. Like *P. annectens*, of Huahine, and *P. turgida* of Raiatea, *it is gradually becoming extinct*.” (Italics mine.) No doubt the species was rare at the time Garrett made his accurate and painstaking surveys, but it is equally clear from my own studies that it is far from being rare or infrequent at present; though it does not occur in all parts of the island, like *hyalina*, it exceeds the latter species in total numbers. Furthermore, the territory *now* occupied includes the eastern quadrant and Taiarapu, all of the southern quadrant, and the western sector as far north as Punaruu. The changes demonstrated by the comparison of the present situation with the state of affairs described by Garrett are clearly of the utmost importance for the present study of distribution and specific modification.

*Partula clara* resembles other species of the genus in its food habits, in its arboreal nature, and in its susceptibility to changes of moisture. It crawls more rapidly than other forms, with the possible exception of *hyalina*. No special nurse-plant is favored, although the herbs and bushes upon which it is found in greater abundance during the daytime may differ in various localities.

#### NUMERICAL DISTRIBUTION OF PARTULA CLARA.

In the case of *hyalina*, a full discussion was given of variations in numerical distribution, and of the interpretation and significance of such variations. Having this as a basis, it will be unnecessary to treat the present case *in extenso*; only the salient points of agreement and of difference need to be established.

The census tables (tables 9 and 18) enumerate the valleys belonging to the continuous area occupied by *clara*, together with the percentage values of this species in the several valley populations; the chart (text-fig. 5), to be described at a later juncture, illustrates in graphic form the extent of the area now inhabited by this species as well as the territory formerly occupied. The first point to be noted is that *clara* does not occur in the northwestern part of Tahiti nui—that is, between Punaruu Valley and Papenoo Valley. This area of absence is relatively drier than the area of presence, and therefore the lower degrees of moisture in the former seem to be limiting conditions to the horizontal spread of this form. We may recall the fact which was duly emphasized earlier, that *hyalina* was most abundant relatively in the very area from which *clara* is absent. The two species appear to be exactly opposite in their general relations to moisture.

Summarizing the facts by quadrants, and including Papenoo as an element of the eastern quadrant, it appears from table 18 that the southern and lower western areas are on the whole more favorable habitats for *clara*. The paucity of individuals in the eastern valleys is due to the recent spread of this species into that sector. Taiarapu has also been populated by *clara* at a relatively recent date, although earlier than the eastern sector.

It is impossible to discern a relation between relative abundance and an ecological peculiarity of valleys inhabited by *clara*, like that between dryness and the frequency of *hyalina*. Owing to the recent spread of *clara* into areas outside of its ancient territory (the southern quadrant), only this should be considered. Vairaharaha and Vaihiria are valleys of the first order of size, and in their populations *clara* forms 27.77 per cent and 23.23 per cent respectively. But in Temarua and Papeiti, also of large size and relative dryness, this species constitutes only 0.87 per cent and 1.84 per cent of 573 and 488 adults in the representative collections. The second-order valleys vary from 0.60 per cent (Taharua) and 0.66 per cent (Apirimaue) to 20.42 per cent (Tereehia). Similarly the smallest valleys vary from 1.44 per cent (Maara) to 8 per cent (Teohu). These last are much more humid than the larger valleys; hence they ought to furnish higher percentages of *clara* if greater wetness materially fosters the numerical increase of this species. The facts do not support this contention. In short, we must conclude that the several valley colonies

vary greatly in constitutional vigor under almost identical ecological conditions in neighboring valleys.

THE SHELL OF PARTULA CLARA; ITS MORPHOLOGICAL VARIATION AND ITS  
GEOGRAPHICAL VARIATION.

GENERAL DESCRIPTION.

The problems of variation, distribution, and evolution are exceedingly involved in the case of *clara*, (*a*) because the shells present different color characters in the populations of various quadrants and valleys, (*b*) because there are dimensional differences in addition to those of color and independent in their variation, and (*c*) because the characters of the unborn young must be treated *pari passu* with the analysis of color resemblances and differences. For these and other reasons it will be necessary to enter into much greater detail than in the case of *hyalina*, although as before a general treatment of the whole population will prove useful for certain purposes as a preliminary to the detailed analysis of the species, region by region and valley by valley.

My own collections comprise 819 adult specimens of this species and 296 immature young individuals. Owing to the fragile nature of the shell, more than 100 adults were unavailable for measurement. The full valley distribution of the whole series of mature snails is given in table 18, together with their classification on the basis of color, in three divisions of light, dark, and banded groups.

The morphological characters of 681 measurable shells are summarized in table 19. On the whole, this species is quite similar to *P. hyalina* from Tahiti (see table 12) and it varies between essentially the same limits. The aperture is distinctly narrower and it is also relatively longer as compared with the total length of the shell—that is, the spire is more closely coiled than in *hyalina*. While the two species might be confused if only the dimensional characters were taken into account, the colors of *clara* always render it clearly recognizable. The general form and color characters of illustrative shells are shown by the valley types of plate 20, figures 14 to 42, and plate 21, figures 1 to 31.

Following the procedure in the case of *hyalina*, we may next compare the shells of the major geographical regions. In Tahiti nui three of the quadrants are inhabited to a considerable extent, while in the fourth sector (the northern) only Papenoo is occupied; for the present it will be best to combine the shells from Papenoo with those of the contiguous eastern sector, instead of taking them by themselves. Taiarapu is the fourth major division inhabited. Table 20 shows that the shells of the eastern sector are the longest, but they are exceeded in width by those of Taiarapu, following the grouped population of the southern quadrant. Because the shells of the last-named are so short, on the whole they are the stoutest group of the four under consideration. As regards the dimensions of the aperture, the eastern and Taiarapu shells prove to be almost identical; this correspondence signifies a close relationship of the two groups and is further emphasized by the qualitative characteristics of color.

TABLE 18.—*Detailed census of the colonies of Partula clara.*

Region and valley.	No. of adult <i>clara</i> .	Per cent of population.	Color-classes.			Varietal designation.
			Light.	Dark.	Bands.	
Western quadrant:						
Punaruu.....	6	0.80	2	4	..	<i>parva</i> .
Maruapoo.....	4	0.42	..	4	..	
Atehi.....	22	4.89	1	21	..	
Papehue.....	35	8.93	23	12	..	<i>incrassa</i> .
Aoua.....	67	5.92	55	4	8	
Orofere.....	49	18.41	20	29	..	
Atitara.....	36	18.94	36	..	..	<i>minor</i> .
Vaitupa.....	44	12.05	43	..	1	
Vaipuarii.....	24	11.76	12	12	..	
Southern quadrant:						
Tiamao.....	24	6.85	22	..	2	<i>angusta</i> .
Tereehia.....	33	20.24	28	5	..	
Maruia.....	3	2.27	1	2	..	
Otuna.....	13	3.40	11	2	..	<i>prima</i> .
Opiriroa.....	8	4.90	..	..	8	
Tearatapu.....	1	3.12	1	..	..	
Vaipoo.....	1	1.58	1	..	..	<i>prima</i> .
Temarua.....	5	0.87	5	..	..	
Papeiti.....	9	1.84	5	4	..	
Teohu.....	40	8.00	27	8	5	<i>marmorata</i> .
Taharua.....	2	0.60	1	..	1	
Moaroa.....	27	5.85	21	6	..	
Faarahi.....	10	1.96	7	1	2	<i>marmorata</i> .
Vairaharaha.....	95	27.77	1	94	..	
Vaihiria.....	92	23.23	44	18	30	
Maara.....	3	1.44	3	..	..	<i>marmorata</i> .
Tenaire.....	19	2.03	19	..	..	
Titaviri.....	12	4.61	12	..	..	
Apirimaue.....	2	0.66	2	..	..	<i>marmorata</i> .
Oopu.....	0	0	..	..	..	
Eastern quadrant:						
Faone.....	3	0.50	3	..	..	<i>marmorata</i> .
Utuufai.....	2	0.56	2	..	..	
Papeiha.....	3	1.05	3	..	..	
Faatautia.....	0	0	..	..	..	<i>marmorata</i> .
Paraura.....	21	2.94	21	..	..	
Vahii.....	0	0	..	..	..	
Mahaena.....	3	1.97	3	..	..	<i>marmorata</i> .
Tiarei.....	0	0	..	..	..	
Faarumai.....	1	0.27	1	..	..	
Farapa.....	0	0	..	..	..	<i>marmorata</i> .
Northern quadrant:						
Papenoo.....	5	0.91	2	0	3	
Taiarapu:						
Tehoro.....	1	0.31	1	..	..	<i>marmorata</i> .
Haavini.....	40	11.87	40	..	..	
Tautira.....	10	3.16	10	..	..	
Aionifaa.....	0	0	..	..	..	<i>marmorata</i> .
Aiurua.....	1	0.44	1	..	..	
Vaiau.....	2	10.00	2	..	..	
Hototunu.....	0	0	..	..	..	<i>marmorata</i> .
Vaiaaia.....	17	10.06	17	..	..	
Aiavaro.....	0	0	..	..	..	
Vavii.....	22	8.05	22	..	..	<i>marmorata</i> .
Vaipoe.....	0	0	..	..	..	
Haoma.....	2	3.77	2	..	..	
Western quadrant...	287	5.46	192	86	9	<i>marmorata</i> .
Southern quadrant...	399	5.78	211	140	48	
Eastern quadrant....	33	0.90	33	..	..	
Northern quadrant...	5	0.08	2	..	3	<i>marmorata</i> .
Taiarapu.....	95	4.28	95	..	..	
Whole island.....	819	3.40	533	226	60	



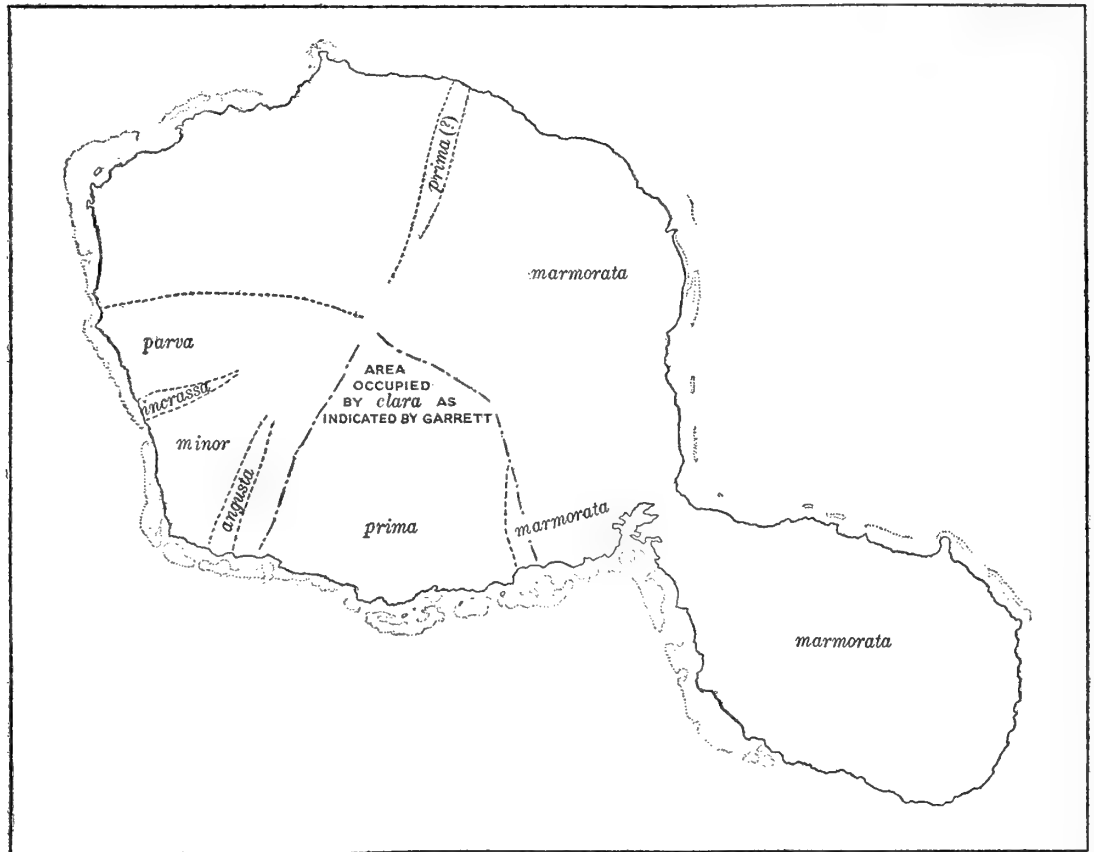
TABLE 19.—*Partula clara*. Tahiti. General characters of 681 adult shells.

Character.	Range (class values).	Mode (class value).	Average.	Standard deviation.
Shell, length, mm.....	12.95 to 17.45	15.35	15.1694±.0195	0.7588±.0138
width, mm.....	7.3 9.9	8.7	8.7573±.0109	.4226±.0077
proportions, per cent.....	50.5 66.5	58.5	57.6967±.0612	2.3751±.0434
Aperture, length, mm.....	7.3 10.5	8.5	8.5611±.0131	.5077±.0093
width, mm.....	5.3 7.3	6.3	6.3511±.0088	.3402±.0062
proportions, per cent.....	62.5 84.5	74.5	74.1285±.0755	2.9251±.0535
Length aperture ÷ length shell, proportions, p. ct..	50.5 66.5	56.5	56.3238±.0572	2.2160±.0406

TABLE 20.—*Partula clara*. Statistical description by regions.

MEAN VALUE.								
Region.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.	
Quadrant:		<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>p. ct.</i>
West.....	233	15.0191±.0352	8.4949±.0193	56.5472±.1015	8.2597±.0194	6.2082±.0148	75.1051±.1066	54.8648±.0841
South.....	337	15.2111±.0261	8.8905±.0121	58.4169±.0823	8.6217±.0163	6.3866±.0115	74.0401±.1192	56.5504±.0656
East.....	33	15.4954±.1008	8.8515±.0520	57.0758±.2520	8.9969±.0563	6.5000±.0400	72.0152±.1713	58.0151±.2240
Taiarapu.....	78	15.3000±.0536	8.9256±.0260	58.2820±.1359	9.0153±.0302	6.5615±.0214	72.4872±.1318	58.9871±.1584
Total population	681	15.1694±.0195	8.7573±.0109	57.6967±.0612	8.5611±.0131	6.3511±.0088	74.1285±.0752	56.3238±.0572
STANDARD DEVIATION.								
Quadrant:								
West.....	233	0.7973±.0249	0.4373±.0136	2.2980±.0716	0.4379±.0137	0.3360±.0104	2.4121±.0753	1.9032±.0594
South.....	337	.7111±.0185	.3306±.0086	2.2431±.0582	.4436±.0115	.3136±.0082	3.2474±.0844	1.7886±.0465
East.....	33	.8585±.0712	.4432±.0367	2.1466±.1777	.4802±.0398	.3411±.0283	1.4590±.1210	1.9088±.1584
Taiarapu.....	78	.7033±.0379	.3410±.0184	1.7842±.0963	.3962±.0213	.2816±.0152	1.7283±.0933	1.3469±.0727
Total population	681	.7588±.0138	.4226±.0077	2.3751±.0434	.5077±.0093	.3402±.0062	2.9170±.0533	2.2160±.0406

We come now to the last and most important stage of the analysis, which involves the consideration of the several valley populations almost *seriatim*. While the foregoing statistical treatment of regional populations is valuable, it does not bring out the sharp differences between the colonies of neighboring valleys in one and the same quadrant. The transitions are often quite abrupt, in the matter of color characteristics or in structural details, or in both respects. To facilitate a clear comprehension of the situation, it may be stated here that no less than six well-marked varieties can be distinguished, and each of these has a definite territory of its own. Some of these varieties exist in the newly acquired parts of the entire inhabited area, while others are found in the old range as specified by Garrett. The distribution of these varieties is charted in text-figure 5; they will be considered in geographical order, beginning with those at the northern limit of the western area of occupation.



TEXT-FIG. 5.—Chart showing the areas of Tahiti occupied by the several primary varieties of *Partula clara*.

***Partula clara parva* var. nov.—Punaruu to Papehue Valleys.**

The shells of the four valleys which constitute the extreme northwestern portion of the range (namely, Punaruu, Maruapoo, Atehi, and Papehue) are characterized by their smaller relative size and by a nearly uniform corneous coloration. They are markedly different in size from the examples of the next valley, Aoua, while they lack the distinct streaks of many shells from Aoua and succeeding valleys. No banded individuals were found in this region. The variety existing in these four valleys is distinguished as *parva*, and its detailed statistical analysis is given in table 21. 59 of the 65 shells were measurable, of which 26 belonged to the “lighter” and 39 to the “darker” class.

The Punaruu shells are illustrated in figures 14 to 17 of plate 20, and they may be regarded as typical of this variety. Only 4 specimens were obtained in Maruapoo Valley out of the total series of 1,112 snails of all ages, and they agree in being by far the smallest obtained anywhere, as shown by figure 17, plate 20, and the statistics of table 21. This is true for their absolute dimensions, but their departures from the average values in proportionate measures are far less marked. In color they belong to the class of the “darker” shells.

The Atehi examples agree more closely with those from Punaruu in size, although their proportionate measures are somewhat distinctive. The “lighter” shells approach a clear white (fig. 20, plate 20), and the “darker” specimens are more

evenly colored than in the more northern valleys (figs. 19 and 21, plate 20, the former somewhat decorticated). The specimen shown in figure 22, plate 20, is an unusually large example from Papehue; it well illustrates the oral aspect of the specimens from this territory.

That the lighter and darker shells are not genetically distinct, like some of the color varieties found elsewhere, is indicated by the fact that some of the former bear dark-colored young, while dark adults sometimes bear lighter young. Satisfactory quantitative determinations have not been possible in the case of the series from this group of valleys, because many individuals were transported alive to America, wherefore the exact parentage of the young snails brought forth during the journey could not be determined.

TABLE 21.—*Partula clara parva*. Statistical description of shell characters.

MEAN VALUE.								
Valley.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.	
		<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>p. ct.</i>
Punaruu...	6	14.7500±.1908	8.5000±.1146	57.8333±.5659	8.1333±.1288	6.1666±.0821	75.6666±.2939	54.8333±.3045
Maruapoo...	3	13.2500±.0954	7.5000±.0636	56.1667±.4856	7.3666±.0367	5.5666±.0367	74.8333±.4856	55.1666±.1836
Atehi.....	20	15.0350±.0647	8.2500±.0414	54.6500±.2199	8.2300±.0408	6.1600±.0318	74.8000±.2616	54.5500±.2919
Papehue....	30	14.9300±.0799	8.4133±.0461	56.1000±.1477	8.4133±.0567	6.2734±.0453	74.6333±.2394	56.0000±.1704
All.....	59	14.8720±.0602	8.3203±.0350	55.6186±.1525	8.2695±.0402	6.1881±.0300	74.8051±.1544	55.3474±.1479
STANDARD DEVIATION.								
Punaruu...	6	0.6928±.1349	0.4163±.0811	2.0548±.4001	0.4678±.0911	0.2981±.0580	1.0671±.2078	1.1055±.2152
Maruapoo...	3	.2449±.0674	.1633±.0449	1.2471±.3433	.0943±.0260	.0943±.0260	1.2471±.3433	.4714±.1298
Atehi.....	20	.4292±.0458	.2747±.0293	1.4585±.1555	.2703±.0288	.2107±.0225	1.7349±.1849	1.9358±.2064
Papehue....	30	.6490±.0565	.3748±.0326	1.2000±.1044	.4609±.0401	.3678±.0320	1.9447±.1692	1.3844±.1204
All.....	59	.6878±.0427	.3994±.0248	1.7377±.1079	.4581±.0284	.3420±.0212	1.7587±.1092	1.6855±.1046

***Partula clara incrassa* var. nov.—Aoua Valley.**

Passing to Aoua, the next valley to the south, a variety is found that is extraordinarily distinct from var. *parva* described above, as well as from the shells that are met with in the succeeding series of valleys. The individuality of this colonial variety is expressed in (a) peculiar color-types, (b) consistent differences in the form of the shell, (c) the thinness of the lip, (d) the occurrence of unique banded mutants, and (e) the occurrence of specimens with a trace of a pillar tooth. The thinner texture of the shell, and especially of the last whorl and lip, may be taken as the diagnostic character of this division; hence the varietal designation, *incrassa*. The shells are illustrated as figures 23 to 36 of plate 20.

In all, 67 adults were secured, and these constitute 5.92 per cent of the population; 55 are plain and light; most of these exhibit the uniform corneous coloration of the species in general (figs. 23 to 27, plate 20), but distinct cross-streaks are superadded in others (figs. 29 and 30, plate 20). A rose-colored spire is sometimes found (fig. 24, plate 20), which is something that occurs nowhere else in this species. Purplish-

brown borders upon the upper whorls (fig. 25, plate 20) are more frequent than in other valley colonies; 4 are plain and darker (fig. 28, plate 20); 8 are variously banded, and in 5 specimens (figs. 34 to 36, plate 20) the banding resembles that of certain shells found to the south, but the other three (figs. 31 to 33, plate 20) are entirely different from anything discovered elsewhere; they are large and slender, in which respects they agree with the characteristic unbanded *incrassa* shells, but in the details of their markings they are absolutely unique.

Of the lighter adults, 20 contained all together 24 well-advanced young, of which 23 were light like their parents, while 11 were dark. One of the 3 dark adults bore 1 light-colored young shell; hence the two color types are not absolutely distinct in hereditary respects. Unfortunately 4 of the banded individuals were not gravid, while 3 others contained only eggs; the eighth with a banded shell bore 2 young, one of which was plain, while the other exhibited characteristic and distinct bands.

TABLE 22.—*Partula clara incrassa*. Aoua Valley.

MEAN VALUE.								
Group.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.	
Plain....	55	<i>mm.</i> 15.3991 ± .0880	<i>mm.</i> 8.5509 ± .0458	<i>p. ct.</i> 55.5909 ± .2011	<i>mm.</i> 8.3364 ± .0428	<i>mm.</i> 6.1473 ± .0327	<i>p. ct.</i> 73.7364 ± .2222	<i>p. ct.</i> 54.1909 ± .2030
Bands....	8	15.8375 ± .2203	9.0250 ± .0628	57.1250 ± .4907	8.6500 ± .1764	6.4000 ± .0983	73.7500 ± .6823	54.2500 ± .5431
All.....	63	15.4547 ± .0826	8.6111 ± .0429	55.7857 ± .1912	8.3762 ± .0444	6.1793 ± .0320	73.7381 ± .2123	54.1984 ± .1901
STANDARD DEVIATION.								
Plain....	55	0.9670 ± .0622	0.5033 ± .0324	2.2096 ± .1421	0.4703 ± .0302	0.3597 ± .0231	2.4417 ± .1570	2.2308 ± .1434
Bands....	8	.9239 ± .1558	.2634 ± .0444	2.0577 ± .3470	.7399 ± .1247	.4123 ± .0695	2.8614 ± .4824	2.2776 ± .3840
All.....	63	.9727 ± .0584	.5049 ± .0303	2.2497 ± .1352	.5230 ± .0314	.3763 ± .0226	2.4990 ± .1501	2.2370 ± .1344

Coming now to the measurable characters of the shell, it appears from the statistics (table 22) that the total length is astonishingly great, far in excess, indeed, of this dimension in *parva*, in the general population of the western quadrant, or in the whole population of the island. It is surpassed only in some of the shells from the eastern quadrant. The width is not much greater, owing to the weak development of the flaring margin of the aperture. Naturally the form of the whole shell is narrow on account of the peculiarities mentioned, although other varieties found in the south show even greater departures from the average value in this character.

The statistics referring to the banded group are not to be taken as entirely significant, because there are so few shells in this class. Furthermore, 5 of the light examples are much smaller than the other 3, and their ground-color is such as to place them with the "dark" plain group; the other 3 shells which exhibit the peculiar banded pattern have a much lighter color. This group, therefore, is not homogeneous, but on the whole its constituents are far longer and stouter than the series of plain shells. Its members are obviously only sporadic products of unbanded parents occupying various positions in the range of such a character as length;

their relationship is indicated by attenuation of the shell as a whole, by the thinness of the lip, by the plain offspring of one of their number, and by the fact that most of them have no counterparts among the banded individuals found further south. Hence they can not be regarded as wanderers from a locality where a distinct stock of striped snails originated.

***Partula clara minor* var. nov.—Orofere to Tiamao Valleys.**

After leaving Aoua Valley, one encounters a variety that maintains the same characters throughout all the valleys to Tiamao, when again there is an abrupt change. The area of its occupation includes Orofere, Atitara, Vaitupa, Vaipuarii, and Tiamao Valleys, of which the last is in the southern sector of the island. The shells of this region are much like the examples taken from the area to the east, which was originally inhabited by *clara*, as described by Garrett; they differ from the latter in some details, however, notably in their extreme breadth and in the brevity of the aperture. It is justifiable for our purposes to separate them as a distinct variety to be designated *minor* (figs. 37 to 42, plate 20, and fig. 1, plate 21; table 23).

The classes of "lighter" (figs. 38 and 41, plate 20) and "darker" (fig. 37, plate 20) shells are not as clearly distinguishable as heretofore, although extreme individuals of both kinds are found in almost all of the valleys now under consideration. All of the Atitara specimens are practically intermediate, while in Vaitupa there is a well-marked group of "medium" individuals (fig. 39, plate 20), dark types being absent. In Tiamao, all of the unbanded specimens are extremely light in ground-color. The banded shells (figs. 40 and 42, plate 20; fig. 1, plate 21) are characteristic.

Here fuller data are at hand regarding the heredity of the color characters, although records for Orofere and Atitara could not be obtained. The facts prove that the color types do not breed true in all cases; 6 "light" Vaitupa adults contained 15 well-grown embryonic young, all of which were "light"; 5 "medium" adults contained 5 "light" and 4 "medium" young, although it must be added that the young of any one parent were alike in color value. In Vaipuarii, 5 adult records are available; 1 light adult bore 4 similar young, while 4 dark adults contained 5 dark young. All of the unbanded Tiamao individuals were light, and they bore 17 equally light young. In brief, a type tends to produce its like, but exceptions occur, as in the case of the Vaitupa series.

Passing to the banded specimens, and the fixity of their color peculiarity, it must be restated that all of the young of unbanded parents were similarly devoid of the rotating marks. The banded individual from Vaitupa gave no data, but the 2 specimens from Tiamao were both gravid; the first of these bore 2 *banded* young, and the second had 1 similar embryo. Scant as the data are, they are at least strongly indicative of a fixed heritable nature of the banded character.

Turning now to the statistical characteristics of the variety under consideration (table 23), we find, as stated earlier, that the shells are about as long as those of var. *parva*, but they are much wider and consequently much stouter. The aperture is also broad in proportion to its length, but otherwise it is not distinctive.

It remains to be noted that the banded specimens of *minor* are decidedly different from shells with bands found in other valleys, and also that in other respects they conform to the type of the unbanded shells of their respective valleys. The latter point is especially clear in the case of the Tiamao shells (fig. 42, plate 20), which have not only the form but also the characteristic light ground-color of their plain associates.

TABLE 23.—*Partula clara minor*. Statistical description.

MEAN VALUE.								
Valley.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.	
		<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>p. ct.</i>
Orofere.....	27	14.9611±.0579	8.4778±.0369	56.5370±.2460	8.3222±.0395	6.2111±.0348	74.2888±.2070	55.5370±.2148
Atitara.....	32	14.6874±.0578	8.2688±.0348	56.4063±.2072	8.0688±.0438	6.1312±.0327	75.6250±.2695	54.8468±.1802
Vaitupa.....	38	15.1605±.0883	8.7315±.0447	57.7631±.2757	8.2948±.0428	6.3105±.0430	76.2631±.2059	54.5527±.2097
Vaipuarii.....	20	14.5700±.0875	8.6700±.0507	59.4000±.2331	8.0600±.0482	6.3000±.0477	77.7000±.2904	55.0500±.2499
Tiamao.....	21	14.8071±.0648	8.5761±.0357	58.0238±.2634	8.2905±.0518	6.2620±.0347	75.5952±.3716	55.6429±.2883
All.....	138	14.8717±.0361	8.5478±.0212	57.5000±.1279	8.2130±.0215	6.2406±.0172	77.1014±.1351	55.0436±.1038
STANDARD DEVIATION.								
Orofere.....	27	0.4458±.0409	0.2845±.0261	1.8950±.1740	0.3047±.0280	0.2685±.0246	1.5947±.1464	1.6551±.1519
Atitara.....	32	.4848±.0409	.2920±.0246	1.7384±.1465	.3678±.0310	.2743±.0231	2.2606±.2695	1.5119±.1274
Vaitupa.....	38	.8068±.0624	.4091±.0317	2.5198±.1950	.3913±.0303	.3932±.0304	1.8824±.1457	1.9172±.1484
Vaipuarii.....	20	.5801±.0618	.3362±.0358	1.5459±.1648	.3200±.0341	.3162±.0337	1.9261±.2053	1.6575±.1767
Tiamao.....	21	.4403±.0458	.2428±.0253	1.7893±.1863	.3517±.0366	.2360±.0246	2.5242±.2630	1.9587±.2041
All.....	138	.6303±.0256	.3703±.0150	2.2295±.0905	.3753±.0152	.3001±.0121	2.3545±.0956	1.8097±.0734

***Partula clara angusta* var nov.—Tereehia Valley.**

The shells of Tereehia Valley, like those of Aoua, are absolutely distinct from those occurring in the adjacent valleys on either side. They are large and slender, with an extraordinarily narrow aperture, and therefore constitute a variety which may be called *angusta*; 28 of 33 specimens were light (figs. 2 and 3, plate 21); and 11 of these bore 22 young snails of the same color class; of the 5 dark examples (fig. 4, plate 21), 2 bore 4 dark young. No banded shells were taken here.

TABLE 24.—*Partula clara angusta*. Statistical description.

Character.	Empirical range.		Empirical mode.	Average.	Standard deviation.
Shell, length, mm.....	14.15	to 17.15	16.55	15.9607±.0999	0.7834±.0706
width, mm.....	7.70	9.70	8.70 and 9.10	8.8429±.0518	.4065±.0366
proportions, per cent.....	50.5	61.5	56.5	55.4286±.3140	2.4629±.2219
Aperture, length, mm.....	7.70	9.50	8.70	8.7714±.0583	.4573±.0412
width, mm.....	5.30	6.70	6.10	5.9785±.0408	.3200±.0288
proportions, per cent.....	63.5	181.5	66.5	67.8928±.4220	3.3095±.2982
Length aperture ÷ length shell, proportions, p. ct..	50.5	58.5	54.5, 55.5	54.8572±.2266	1.7771±.1601

<sup>1</sup>Only 1 shell exceeds 71.5 per cent in this dimension.

The most obvious distinctive character is the narrowness of the aperture (table 24), that differs from the like feature of all other valley colonies to degrees that are statistically enormous. Comparing the Tereehia shells with those of

Tiamao, its neighbor to the west, it appears that the former differ from the latter to the extent of 7.7024 per cent, which difference has a probable error of only 0.5623 per cent. Making the same comparison with *clara* as it exists in Otuna Valley, next to Tereehia on the east, the difference is 7.2739 per cent with a probable error of 0.4600. In short, the differences in question are more than 13 and 15 times their probable errors. Great emphasis must be put upon the fact that the diagnostic character of this variety is a proportionate one and not an absolute dimension such as total length; conceivably it is less subject, therefore, to modification by factors which might affect the extent of growth. It is a matter of unique and specific *form*.

*Partula clara prima* var. nov.—Maruia to Vaihiria Valleys.

It has been noted above that an abrupt change in the character of the *clara* shells takes place upon passing beyond Tereehia Valley. Afterwards, for many miles, the species presents essentially the same characteristics as far as the ridge to the eastward of Vaihiria Valley, beyond which the color characters are distinctly different. This extensive region between and including Maruia and Vaihiria Valleys covers the greater part of the original habitat of *clara*. For this and other reasons the variety occurring in the specified sector is distinguished as *prima* (figs. 5 to 23, plate 21, and table 25).

TABLE 25.—*Partula clara prima*. Statistical description of shell characters, by valleys. Mean value.

Valley.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.	
		<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>p. ct.</i>
Otuna.....	9	15.4833±.0959	9.0556±.0842	58.2778±.2955	8.6334±.0874	6.4778±.0616	75.1667±.1835	55.9444±.4384
Opiroa.....	6	15.3500±.0953	8.7333±.0587	57.0000±.3812	8.3333±.0378	6.3333±.0205	75.3334±.1892	54.6666±.2938
Temarua.....	5	14.8100±.1054	8.5800±.0614	57.5000±.3302	8.4600±.0703	6.1800±.0482	72.7000±.2255	57.4600±.3919
Papeiti.....	9	14.6166±.0719	8.5000±.0561	58.1667±.1498	8.3000±.0971	6.2333±.0670	75.0555±.5624	56.3889±.3885
Teohu.....	31	15.2629±.0811	9.0226±.0419	58.9194±.2914	8.7516±.0430	6.4807±.0366	73.7580±.2196	57.3710±.2660
Moaroa.....	25	15.6500±.0715	9.1480±.0291	58.2600±.2595	8.9800±.0463	6.6440±.0259	73.7400±.2329	57.1000±.1619
Faarahi—all ..	9	15.6833±.1249	8.9222±.0578	56.8333±.3514	8.7222±.0684	6.5222±.0515	74.5000±.3179	55.6111±.1273
bands ..	2	15.5000±.2146	8.8000±.0477	56.5000±.9538	8.8000±.1430	6.6000±.0477	74.5000±.4769	56.5000±.0
Vairaharaha— dark.....	94	14.7163±.0312	8.8350±.0160	60.0125±.0931	8.2875±.0551	6.3725±.0122	76.9625±.0997	56.1438±.0601
Vaihiria—light ..	36	15.3167±.0728	8.9722±.0336	58.5277±.2256	8.6556±.0468	6.5722±.0336	74.1111±.2433	56.3056±.2014
dark ..	12	15.3000±.0887	9.0500±.0453	58.9166±.2443	9.0166±.0462	6.6000±.0337	73.4167±.2444	58.8333±.2295
bands ..	27	15.0611±.0768	8.8703±.0398	58.9074±.2127	8.6182±.0470	6.3963±.0356	74.1667±.2120	57.0555±.1706
all ....	75	15.2220±.0440	8.9720±.0229	58.7200±.1166	8.7000±.0311	6.4440±.0220	74.0200±.1464	56.9800±.1384
Whole region....	255	15.1206±.0263	8.9227±.0131	58.9431±.0792	8.5808±.0173	6.4349±.0109	74.9431±.0933	56.6216±.0666

Of 306 adult individuals, 125 are light and plain, 135 are dark and plain, while 46 are banded in various ways. The members of the first and second classes have more or less well-marked darker streaks upon the general corneous ground-color, as in *incrassa*, *minor*, and *angusta*. The banded shells are entirely different from those described earlier. Sometimes all three classes are represented in a valley population, but in other cases the collections comprise two color-classes, or only one. It is necessary to describe the facts valley by valley, omitting those in which very few specimens were secured.

*Otuna Valley*.—Of 13 shells, 11 were light and 2 were dark. The latter agree closely with the measurable examples of the former class, as far as structural characters are concerned. The figures given in table 25 refer to the entire group; 3 light individuals contained 6 similar young, while 1 dark specimen bore 2 dark young.

*Opiriroa Valley*.—All of the 8 shells were banded (figs. 5, 6, and 7, plate 21) and 5 of the animals bore 8 banded young; no unmarked young shells were present. This is a well-established color form that breeds true to its distinctive character, like nearly all of the banded specimens of *clara* which supply reliable data.

In the details of the banded pattern, these shells are unique. A major stripe is sharply marked in most of them, and this corresponds with the single narrow band of the Tiamao shells described above. In addition, there are sutural and umbilical bands, less clearly marked, while midway between the major stripe and the sutural band there is another vague marking. A certain amount of suffusion between the bands occurs in all of the specimens. In structural characters (table 25) the shells differ somewhat from those of contiguous valleys.

*Temarua and Papeiti Valleys*.—These valleys are virtually divisions of one large element. From Orofere Valley, on the western side, to this point, the ravines are relatively narrow and shallow, but on passing Tearatapu, one finds in Temarua a valley of the largest class, both as regards its width and inward radial extent. The boundary ridge on the west is very steep and high (plate 17a). A long spur from the mass which is crowned by Mount Tetufera divides upper Temarua from Papeiti, the lesser branch. This spur terminates about a mile from the shore and at some distance inland from the buttresses which form the limits of the valley's mouth. Snails are not numerous, however, until the valleys separate. All of the individuals of *clara* were taken *within* the two valleys, and hence they may be viewed as two distinct series, even though of necessity these must be closely related to each other, as the figures demonstrate.

The 5 adult examples from Temarua were all light; 4 were gravid and contained 5 light young snails.

Of 9 adults from Papeiti, 5 were light, but none bore advanced young; 2 of the 4 dark individuals contained 4 medium young, not quite as dark as their parents.

*Teohu Valley*.—This is a small gully in the triangular land-mass, between Temarua and Taharua, which rises inland to the peak of Mount Tetufera. The outward slopes of the terminal ridges are thickly covered with vegetation of low growth and, as much rain falls on this side of the island, these slopes are sufficiently moist to form a suitable habitat for *clara*, as well as for *otaheitana* and *hyalina*. Most of the specimens, however, were taken within Teohu Valley itself, where they are relatively abundant, forming 8 per cent of the whole snail population.

In Teohu and its neighborhood, the shell is especially thin, and the black reticulated pigment of the mantle-wall is distinctly visible through the shell.

The light individuals (fig. 8, plate 21) preponderate, numbering 27 out of 35; 10 were gravid and provided 13 light-colored young; of the 8 dark-shelled animals (fig. 9, plate 21), 2 were gravid and contained 4 dark-shelled young. One of the





A. The region about the coastward portions of Tamarua Valley (in the distance), Papeiti Valley, (middle distance), and the mouth of Teohu Valley (foreground, at the right).



B. Vairaharaha Valley (on the left) and Vaihiria Valley (on the right), looking inland from near their confluent mouths.



banded snails (figs. 10 and 11, plate 21) bore 3 *banded* offspring, but the embryos of the other examples were too immature to exhibit their definitive colors or patterns.

The striped snails are peculiar in the distinctness of their major band and in the clearer development of the sutural band. In one of them an intermediate band appears, although this is far weaker than in the Opiriroa shells. Statistically, these two shells stand near the median values of their unbanded associates.

*Taharua Valley*.—Only 2 adult snails were secured in this large and deep valley, a fact that is noteworthy in connection with the relatively large collection from Teohu. One of these is an ordinary light shell, but the other is banded in a peculiar way (fig. 12, plate 21); it is like a Teohu shell in which the median band is broad and almost fused with the major band. In a way it is transitional to the striped shells of Faarahi beyond.

*Moaroa Valley*.—The Moaroa shells are described statistically (table 25) only to illustrate the variation in colonial characteristics. All of the 27 shells are unbanded, and present no peculiar features.

*Faarahi Valley*.—Here 10 specimens were secured, 7 light, 1 dark, and 2 banded (figs. 13 and 14, plate 21). Each kind breeds true to its color type: 12 light young from 6 light parents, 2 dark young from the single dark specimen, and 3 striped young from the 2 banded individuals.

A statistical comparison of the two aberrant snails with the whole group (which of course includes these) shows (table 25) some deviation on the part of the banded specimens, but on the whole they agree with the others of their locality. This result is similar to that established in the case of *incrassa*, from Aoua Valley. It supports the conclusion that banded specimens arise from unbanded forms in various places and that the former do not constitute a distinct widely distributed stock. We shall return to this subject in the summary, after adducing additional facts.

*Vairaharaha Valley*.—In this great valley, as well as in its close neighbor, Vaihiria, relative large numbers of *clara* were taken. The figures are 95 and 92, respectively, and the corresponding population percentages are 27.77 and 23.23. Yet the collections of *clara* are strikingly different, in spite of the fact that these two large valley areas are confluent at their mouths (plate 17*b*). All of the Vairaharaha shells were taken on the west border of the stream, while the Vaihiria collections were made mainly on the east side of the Vaihiria River. Of the shells from Vairaharaha, 94 are dark brown, with purple-brown apices and purplish suffusion on the lip (figs. 15 and 16, plate 21). The last-mentioned character is not found to the west and north, and the second also is very rarely displayed in regions previously discussed. The single remaining shell is a typical light example, similar to a more abundant series from Vaihiria. The statistical description (table 25) refers to the 94 dark shells. The most notable features are the stoutness of the shell and the relative breadth of the aperture. The single light shell is a large example, agreeing with many belonging to the dark series. Data relating to the heredity of color characters were provided by 33 specimens whose 48 young belonged to the parental color-class. The color of these embryonic shells is not so deep as that of the full-grown or of the adolescent

snail, but it is recognizably different from the light tinge of a shell belonging to the contrasted class.

*Vaihiria Valley*.—In this area, *clara* is astonishingly abundant, especially in the lower part of the valley, where it occurs upon the vanilla vines as well as upon the trees and shrubs that usually harbor it. The greater abundance of snails belonging to all three primary color classes makes it possible to obtain more extensive data bearing upon the heredity of such color characters and also to obtain more accurate determinations of structural similarities and differences. Of the 92 adults secured, 44 are light (fig. 17, plate 21), 18 belong to the darker class (figs. 18 and 23, plate 21), while 30 are banded (figs. 19 to 22, plate 21). The last-named are almost all marked with a broad brown girdle consisting of the major band fused across with the intermediate band between it and the sutural marking, as will appear from a comparison of the *Vaihiria* shells with those from *Opiriroa*. A few show only slight suffusion of this zone (fig. 19, plate 21), thus forming intermediates connecting the *Teohu*, *Opiriroa*, and *Tiamao* varieties with the typical *Vaihiria* shells, and with those from *Faarahi*. Among the lighter individuals, 14 bore 19 young assignable to the same color class. Only 4 with dark shells contained advanced young, all 8 of which were of the darker group. 16 banded snails furnished 20 young, with a distinct but narrow band in the position of the so-called major stripe of the adult. Turning to the measurements of the shells (table 25), it is plain that the three color-types are statistically distinct in some respects. It would seem that the banded class is more like the light division of unmarked forms, and this is further indicated by the fact that the embryonic shells of the banded snails usually have a light ground-color.

***Partula clara marmorata* var. nov.—Maara to Farapa Valleys.**

Beyond the ridge that forms the eastern boundary of *Vaihiria Valley*, the shells of *clara* differ in certain characters from all varieties previously described. Their coloration is their most distinctive peculiarity. The ground-color is light, and upon this there are usually few or many transverse brownish markings that are not sharply defined, like the streaks present in the varieties already considered, and hence the shells present a somewhat marbled appearance; this variety is named *marmorata* (figs. 24 to 29, plate 21, and table 26). In addition, the whole shell is thick and chalky in texture, and the mantle-walls are often impregnated or incrustated with calcareous matter; the last character is not duplicated in any other primary variety. No banded examples were found in any part of the wide territory inhabited by *marmorata*.

The valleys adjacent to *Vaihiria* on the east—namely, *Maara* and *Tenaire*—are within the area specified by Garrett as the territory occupied by *clara* in his time. Both in the chart and in the verbal description given by that writer this species is represented as entirely absent from *Taiarapu* and from the eastern quadrant. At present, however, this particular variety of *marmorata* is found, though sparingly as a rule, in valleys on all four sides of the peninsula, and up on the eastern side of *Tahiti nui* as far as *Faarumai*; only one valley beyond, viz, *Papenoo*, is

inhabited by *clara*. Hence *marmorata* is the most widely distributed variety of *clara*, and it is also the most recently dispersed color-form of this species.

Although the distinctive coloration varies little throughout this wide range, the measurable shell characters are much diversified. The single example from Apirimaue (fig. 25, plate 21) is the largest of the entire collection except one other shell of the variety *incrassa* from Aoua Valley. A specimen from Haavini, in Taiarapu, is very nearly the shortest of the whole series; the widest of all is likewise an example of *marmorata*, from Faarumai. The characters of the aperture are also extraordinarily variable; the relative width of a Maara specimen is even less than that of the narrowest *angusta* examples. Decortication sometimes occurs, as in the shells from Mahaena (fig. 26, plate 21). Of all color-types, *marmorata* is, in a word, by far the most variable in the structural characters of the shell.

TABLE 26.—*Partula clara marmorata*. Statistical description by valleys and by regions.

MEAN VALUE.								
Region.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.	
		<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>p. ct.</i>
Maara...	3	15.8500±.2403	8.5666±.0735	53.8333±.3675	8.3333±.0735	5.8334±.0735	65.5000±.8425	55.8333±.3675
Tenaire...	17	15.6323±.1529	8.8647±.0511	56.6177±.3011	9.0294±.0816	6.4529±.0774	71.3824±.3314	57.5588±.2833
Titaviri...	12	15.1500±.1101	8.9666±.0681	59.0833±.2312	9.0000±.0626	6.6000±.0539	73.2500±.1967	59.4167±.0960
Vavii...	19	15.4605±.1109	8.9105±.0501	58.1843±.2191	9.1526±.0563	6.5947±.0406	71.7631±.2291	59.2369±.1492
Vaiaaia...	15	15.6300±.1115	9.1400±.0512	58.4334±.2808	9.1800±.0782	6.7133±.0516	72.9000±.2970	58.7000±.2638
Tautira...	10	15.1700±.0653	8.9800±.0639	58.9000±.3721	9.0600±.0533	6.6000±.0286	73.0000±.3602	59.8000±.2144
Haavini...	30	15.0700±.0900	8.7733±.0409	58.2334±.2440	8.8267±.0452	6.4667±.0351	72.7666±.1957	58.8333±.1631
Paraurea...	19	15.4289±.0836	8.7421±.0631	56.6579±.2669	8.9421±.0607	6.4579±.0517	71.8157±.2410	57.9736±.2719
Southern...	33	15.5318±.1036	8.8819±.0402	57.1364±.2754	9.0213±.0510	6.4394±.0515	71.2879±.1147	58.0152±.2086
Taiarapu...	78	15.3000±.0536	8.9256±.0260	58.2820±.1359	9.0153±.0302	6.5615±.0214	72.4872±.1318	58.9871±.1037
Eastern...	28	15.4460±.1148	8.8000±.0572	56.9286±.2819	9.0142±.0655	6.4928±.0465	71.7500±.1791	58.3571±.2378
All.....	139	15.3776±.0456	8.8914±.0208	57.7374±.1201	9.0165±.0247	6.5187±.0198	72.0540±.1216	58.6295±.0930
STANDARD DEVIATION.								
Maara...	3	0.6164±.1697	0.1885±.0519	0.9428±.2596	0.1885±.0519	0.1885±.0519	2.1613±.5952	0.9428±.2596
Tenaire...	17	.9344±.1081	.3123±.0361	1.8406±.2130	.4991±.0577	.4729±.0547	2.0258±.2344	1.7316±.2003
Titaviri...	12	.5656±.0779	.3496±.0481	1.1873±.1635	.3214±.0442	.2768±.0381	1.0103±.1391	.4930±.0679
Vavii...	19	.7166±.0784	.3242±.0355	1.4161±.1549	.3640±.0398	.2625±.0287	1.4811±.1620	.9647±.1055
Vaiaaia...	15	.6403±.0788	.2939±.0362	1.6117±.1984	.4488±.0552	.2963±.0365	1.7048±.2099	1.5143±.1864
Tautira...	10	.3059±.0461	.2993±.0451	1.7435±.2629	.2497±.0376	.1341±.0202	1.6881±.2546	1.0049±.1515
Haavini...	30	.7311±.0636	.3326±.0289	1.9821±.1724	.3669±.0319	.2849±.0248	1.5902±.1383	1.3249±.1153
Paraurea...	19	.5405±.0591	.4082±.0446	1.7242±.1886	.3924±.0429	.3345±.0366	1.5577±.1704	1.7579±.1923
Southern...	33	.8829±.0733	.3424±.0284	2.3460±.1947	.4346±.0361	.4389±.0364	.9772±.0811	1.7773±.1475
Taiarapu...	78	.7033±.0379	.3410±.0184	1.7842±.0963	.3969±.0213	.2816±.0152	1.7283±.0933	1.3469±.0727
Eastern...	28	.9007±.0811	.4488±.0404	2.2108±.1992	.5139±.0463	.3644±.0328	1.4047±.1266	1.8654±.1681
All.....	139	.7978±.0323	.3645±.0148	2.1003±.0851	.4310±.1075	.3459±.0140	2.1261±.0861	1.6264±.0659

The abrupt change observed in passing from Vaihira to Maara—from the range of *prima* to the territory of *marmorata*—is emphasized by the almost unique conditions of the Maara shells (table 26). Only 3 specimens were taken in this small valley, but they are strikingly consistent in their short, narrow, and relatively

contracted apertures (fig. 24, plate 21). There is a progressive change in virtually all of the shell characters in passing to *Tenaire* and further to *Titaviri* (table 26). The shells become shorter and wider and relatively stouter, while the apertures become somewhat longer, much wider, and relatively broader; the same sequence appears in the proportion of aperture length to shell length.

The collections from the valleys of Taiarapu present no features of special interest, aside from their diversity. Of the valleys in the eastern quadrant, only Paraura afforded a fair collection; this series is in general more like the southern shells than like those of the peninsula. The resemblance is emphasized when the comparison is made by regions (table 26), when all of the smaller valley collections are taken into account as well as those of the representative valleys.

As there are no banded or dark-colored shells belonging to this variety, the statistics of heredity are of little interest beyond the fact that neither of the two general color-classes lacking among the adults is represented among the embryonic but advanced young; of the last, there are 109 in all.

*Partula clara* var. *prima* (?).—Papenoo Valley.

The last valley on the east and north which is inhabited by *clara* is Papenoo, a very large element in the series of valleys situated in the northern quadrant. The discovery of this species in a locality so remote from its original headquarters is less remarkable than the fact that the shells found in Papenoo are entirely different from *marmorata*, whose range, we have seen, extends the whole distance from this point to the former boundaries of the species. From the bushes of the level valley floor 5 living specimens were secured in 1906 about 2 miles inward from the coast; of these, 2 were light and unbanded (fig. 30, plate 21), while 3 were banded like the *Vaihiria* examples (fig. 31, plate 21). In 1908 and again in 1909 this valley was visited in order to secure additional specimens of *clara*, if possible, as well as further information regarding the separate species of *stolida* Pease, reported by Garrett as occurring *only* in this valley. In spite of prolonged search, however, no additional *clara* were obtained. Apparently the 1906 examples belonged to a small localized colony existing in the lowlands.

The resemblance of this colony to the *Vaihiria* shells is marked especially by the character of the banded shells; the unstriped light examples are also like *prima* and differ absolutely from *marmorata*. In statistical characters, furthermore (table 27), there appears to be a closer relation to var. *prima* than to any other regional variety.

TABLE 27.—Shell characters of five *Partula clara* from Papenoo Valley.

Character.	Mean value.	Standard deviation.
Shell, length, mm.....	15.7600±.1513	0.5018±.1071
width, mm.....	9.1400±.0800	.2653±.0566
proportions, per cent.....	57.9000±.4514	1.4966±.3194
Aperture, length, mm.....	8.9000±.0539	.1788±.0381
width, mm.....	6.5400±.0451	.1496±.0319
proportions, per cent.....	73.5000±.1907	.6324±.1349
Length aperture ÷ length shell, proportions, p. ct..	56.1000±.1477	.4898±.1045

To account for the presence in Papenoo Valley of shells like those of the opposite side of the island, clearly different from var. *marmorata* of the eastern quadrant, two explanations suggest themselves. It is possible that *Vaihiria* snails might have been introduced into Papenoo upon vanilla cuttings; but the two valleys in question are far apart, and their native inhabitants do not have much intercourse because they belong to different tribal subdivisions formerly at enmity. Vanilla plants have been taken from *Vaihiria* to several valleys of Taiarapu, yet banded examples and the closely lined light shells of var. *prima* are entirely lacking in the peninsula. It does not seem probable that human agencies have been responsible for the introduction of the southern *prima* into the distant northern region of Papenoo.

In the second place, migrants may have crossed the ridge which separates the upper portions of *Vaihiria* and Papenoo, where descendants may have worked their way down to the lowlands. A complete exploration of the great central basin of Papenoo would certainly prove or disprove this explanation, but in spite of all efforts, such a thorough investigation was impossible during the periods of field-work. The sharp difference between the shells in question and those of Faarumai, which are typical *marmorata*, together with the other circumstances noted, make the second interpretation more plausible than the assumption that human agency has transplanted a southern form into a distant valley of the north.

#### FECUNDITY.

This species is similar to *hyalina* in the relatively large number of young and eggs present in the brood-pouch of a gravid individual. The egg-shell is also transparent, a condition that is not found in the remaining Tahitian species until the young snail is virtually ready to emerge. Anachronisms in the serial order of the embryonic individuals are nearly as rare as in *hyalina*; only two instances appear in the records.

TABLE 28.—*Partula clara*. Statistics of fecundity.

Region.	No. of stations.	No. of records.	No. of gravid snails.	Per cent gravid.	No. of young and eggs.	Average for gravid.	Average for all.
Western quadrant....	9	164	84	51.2	235	2.79	1.37
Southern quadrant....	18	277	235	84.8	910	3.87	3.28
Eastern quadrant.....	7	31	22	70.9	79	3.59	3.51
Taiarapu.....	7	62	57	91.9	228	4.00	3.67
All.....	41	534	398	74.5	1,452	3.64	2.71

The statistics of fecundity are given in summary in table 28, comprising more than 500 records of snails belonging to the colonies of 41 valleys. The percentage of gravid individuals is far higher than in *hyalina*, but the average number of eggs and young is less, the figure being 3.75 per cent for *hyalina* and 3.64 for *clara*. Nevertheless, the average for *all* individuals, 2.71 per cent, is higher than in the other species, 2.44 per cent.

Among the 534 recorded individuals, 136 were barren; the embryonic contents of the other varied as follows:

No. of eggs and young:	1	2	3	4	5	6	7	8	9	10
No. of adults:	51	71	80	73	55	37	22	6	2	1

It seems that a given adult breeds intermittently and produces a series of offspring after a period of reproductive rest. When the brood-chamber contains only three or four individuals, either they range from newly formed eggs to very young snails, or they stand at the older end of the series and are ready or nearly ready to be born. In the former case a resumption of breeding activity is indicated, while in the latter the parent is about to close a period of reproductive effort.

Much variation in colonies also appears. In some cases, such as Moaroa, only 50 per cent of the adults were gravid. Of 23 adults taken in Teohu, 20 bore young and eggs. Vaihiria and Vairaharaha are scarcely separated at their lower ends and are therefore so close that environmental conditions are practically the same; yet their gravid adults are 83.9 per cent and 91.3 per cent, thus differing markedly in their productivity at one and the same season. Again, Maara is next to Vaihiria on the east; all 3 of the adults taken were bearing, but there were only 3 offspring in all—an average of 1. Treating the returns of this case as we did those for *hyalina*, it is found that for every 100 adult snails 74 are bearing the reproductive burden for the time and they produce 271 young; therefore 171 of this generation probably die before reaching reproductive maturity themselves, and hence elimination would seem to be slightly more severe than in the case of *hyalina*.

#### THE EVOLUTIONARY SIGNIFICANCE OF THE VARIATION AND DISTRIBUTION OF PARTULA CLARA.

##### SUMMARY AND DISCUSSION.

It now remains to bring together the important points of the foregoing detailed descriptions and to state clearly the general results of an evolutionary significance. The situation in this case is obviously very different in many respects from that of *hyalina*; it will become evident that the differences in question materially favor the establishment of definite conclusions regarding the history of *clara* and that such conclusions support and amplify the interpretation of evolution in the genus *Partula*, based upon the first case. The facts indicate that *clara* is a species which had been greatly reduced in numbers, but which subsequently recovered its vigor and increased in numbers, migrating into wide areas formerly unpeopled by it and differentiating often by mutation into numerous subordinate types in the course of its recent dispersal.

I. *Partula clara*, which exists only in Tahiti, was formerly a rare species, while now it is relatively abundant in certain localities. In Garrett's monograph (1884) he says that *clara* is "a rare species, found on foliage in the upper portions of the valleys in the southwest part of Tahiti." In 1879, in a letter to Hartmann (ref. in



Smith, Annotated List, 1902), he wrote: "*P. clara* is *not* a Moorea species. It is a very rare local Tahiti species and, like *annectens* and *turgida*, appears to be gradually becoming extinct. *I have only three examples in my collection.*"<sup>1</sup> In view of these specific statements, based upon Garrett's painstaking and detailed study of all parts of Tahiti, as evidenced by his circumstantial account of the snail populations of various valleys designated by name, there can be no doubt that this species was actually very rare in his time and in great danger of becoming extinct.

Mayer, in 1899, obtained 61 snails from Vaihiria Valley, an important element of the range of *clara*. Apparently 5 light dextral shells and 1 dark dextral shell among these were *clara*, although Mayer regarded them as dextral varieties of *sinistrorsa*, a form of *otaheitana*. In my own collections, 619 adult and adolescent snails were taken in Vaihiria, and none of them is a dextral *otaheitana*; hence I judge that Mayer's dextral shells were *clara*. The further point of interest is that Mayer's dextral snails amounted to about 10 per cent of his whole collection in this valley. Of my adult snails, 23.23 per cent from this locality belong to the species under consideration. It is certain, therefore, that a great increase in relative numbers has come about in a very few years.

Finally, in this connection, we may note the figures denoting the relative frequency of *P. clara* in the island as a whole. The yield of 43 valleys amounted to 819 adult *clara* individuals, and of these valleys the general populations numbered 16,005 adults; thus *clara* forms 5.1 per cent of the total population in the valleys definitely inhabited. But the whole range of this species includes 52 valleys, for 9 valleys in the inhabited quadrants or major regions did not disclose *clara* among their inhabitants. The total adult population of these 52 valleys was 18,015, and the 819 snails of the present species amount to 4.5 per cent of this figure. Lastly, of the 24,085 adults representing the inhabitants of the whole island, the 819 *P. clara* constitute 3.4 per cent. According to the point of view, therefore, this species forms 5.1 per cent, 4.5 per cent, or 3.4 per cent of the population. In brief, then, in 1879 only 3 specimens of *clara* were in Garrett's hands; in 1899 Mayer obtained a collection from Vaihiria, of which 10 per cent were *clara*, while from the same valleys, from 1906 to 1909 inclusive, I obtained 23.13 per cent of this species; *clara* forms 5.1 per cent or 4.5 per cent of the snail fauna of its range and 3.4 per cent of the whole population. It is obvious that it has materially increased in numbers during recent years.

II. *Formerly greatly restricted in its habitat, Partula clara now ranges over about four-fifths of the entire island of Tahiti.* From Garrett's rough chart, published by Hartmann, given in its original and in its corrected form in text-figures 2 and 3, the area inhabited in his time extended from about Tereehia to Tenaire or Titaviri Valleys. It has been shown that now this range is increased so as to include the western sector as far northward as Punaruu, all of Tairapu, and all of the eastern quadrant to and including Papenoo Valley. It is certain that these newly-won localities were not peopled by *clara* in Garrett's time. For instance, he correctly describes the forms of

<sup>1</sup>The italics of the last sentence are of the present author.

*otaheitana*, but makes no mention of *clara* in Orofere, in which valley at the present time more than 18 per cent of the adults are *clara*. Neither the chart nor the verbal descriptions refer to *clara* as existing in the peninsula Taiarapu, in which this species now forms 4.28 per cent of my collections of adult animals. Hence, the wider range of *clara* has only recently been attained, like its greater relative abundance.

III. *In attaining its present wide range, Partula clara has come to exhibit distinct variations in the characters of its shell, and to some degree also in coloration.* It is impossible to obtain a definite basis for comparing these characteristics with the qualities of *clara* in Garrett's time, although, as regards the matter of coloration, it is evident that the three major types were present when the species was discovered. Pease speaks of the color of the shell as "corneous or pale chestnut, variegated with longitudinal strigations," and of varieties with one, two, or three bands.

From the detailed descriptions of this memoir, it will be seen that the structural characters of the shells vary considerably from valley to valley; the same is true of the color characters of colonies taken as wholes, giving due regard to the proportionate numerical values of the three major color-types. Furthermore, the relative abundance of *clara* varies like the other characters of the several valley colonies. It is even less possible than in the case of *hyalina* to refer the variations noted to environmental factors.

The banded examples prove to be essentially different from one another when widely separated valleys are compared, and in each valley the structural characters of such shells approximate those of the unbanded associates; this is especially marked in the analysis of the Aoua and Vaihiria colonies. It would seem, then, that we are not dealing with three color-types differentiated in an original locality, which types have subsequently spread in company over neighboring areas, although this may be true for closely connected valleys such as those from Taharua to Vaihiria. What we do find is a dispersed series of unbanded forms, which have produced characteristic banded mutants in certain but not in all of their valley habitats; in the case of *marmorata* such mutations in color do not present themselves, although structural deviations are exhibited by the subordinate types of separated valleys.

Although the colonies of the valleys now inhabited vary considerably, they appear to group themselves about certain common varietal types, which have been designated in the foregoing description by proper names. That procedure is perhaps not entirely justified by the facts provided by this species alone, for the varieties overlap in many cases. But when the many subordinate types of the complex species *P. otaheitana* are described in a subsequent section of this volume, it will appear that the condition of partial differentiation into more or less clearly demarcated varieties, presented by *clara* as a whole, leads to an actual and distinct discontinuity of similarly produced varietal types in a species which far earlier passed through the evolutionary stages in which *clara* now appears. Hence there is ample justification for the procedure in this case.

The six recognizable varieties of *Partula clara* are defined in statistical terms by the figures of table 29, which give the respective mean values of all seven meas-

ured characters; the color-characters can not be formulated in quantitative terms in the same way, and hence they may be passed over in the present summary, although it must not be forgotten that in the case of such a form as *marmorata* it is a quality of this nature that serves as a diagnostic varietal distinction. In the next place, the statistical values of the differences in mean value, in progressive order, are given in table 30, with their probable errors. Finally, table 31 shows graphically the changes in progressive geographical order, in the total ranges as well as in the mean values of the several characters. Combining all of the available

TABLE 29.—*Partula clara*. Statistical description of primary varieties. Mean value.

Variety.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.	
		<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>p. ct.</i>
<i>parva</i> .....	59	14.8720 ± .0602	8.3203 ± .0350	55.6186 ± .1525	8.2695 ± .0402	6.1881 ± .0300	74.8051 ± .1544	55.3474 ± .1479
<i>incrassa</i> .....	63	15.4547 ± .0826	8.6111 ± .0429	55.7857 ± .1912	8.3762 ± .0444	6.1793 ± .0320	73.7381 ± .2123	54.1984 ± .1901
<i>minor</i> .....	138	14.8717 ± .0361	8.5478 ± .0212	57.5000 ± .1279	8.2130 ± .0215	6.2406 ± .0172	77.1014 ± .1351	55.0436 ± .1038
<i>angusta</i> .....	28	15.9607 ± .0999	8.8429 ± .0518	55.4286 ± .3140	8.7714 ± .0583	5.9785 ± .0408	67.8928 ± .4220	54.8572 ± .2266
<i>prima</i> .....	255	15.1206 ± .0263	8.9227 ± .0131	58.9431 ± .0792	8.5808 ± .0173	6.4349 ± .0109	74.9431 ± .0933	56.6216 ± .0666
<i>marmorata</i> :								
Southern .....	33	15.5318 ± .1036	8.8819 ± .0402	57.1364 ± .2754	9.0213 ± .0510	6.4394 ± .0515	71.2879 ± .1147	58.0152 ± .2086
Taiarapu .....	78	15.3000 ± .0536	8.9256 ± .0260	58.2820 ± .1359	9.0153 ± .0302	6.5615 ± .0214	72.4872 ± .1318	58.9871 ± .1037
Eastern .....	28	15.4460 ± .1148	8.8000 ± .0572	56.9286 ± .2819	9.0142 ± .0655	6.4928 ± .0465	71.7500 ± .1791	58.3571 ± .2378
<i>prima</i> (?):								
Papenoo .....	5	15.7600 ± .1513	9.1400 ± .0800	57.9000 ± .4514	8.9000 ± .0539	6.5400 ± .0451	73.5000 ± .1907	56.1000 ± .1477

TABLE 30.—*Partula clara*. Progressive comparisons of primary varieties. Mean value.

Variety.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.
	Length.	Width.	Proportions.	Length.	Width.	Proportions.	
	<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>p. ct.</i>
<i>parva</i> .....	+0.5827 ± .1022	+0.2908 ± .0554	[+0.1671 ± .2445]	[+0.1067 ± .0599]	[−0.0088 ± .0439]	−1.0670 ± .2625	−1.1490 ± .2409
<i>incrassa</i> .....	−.5830 ± .0901	[−.0633 ± .0478]	+1.7143 ± .2300	−.1632 ± .0493	[+ .0613 ± .0363]	+3.3633 ± .2516	+ .8452 ± .2169
<i>minor</i> .....	+1.0890 ± .1062	+ .2951 ± .0560	−2.0714 ± .3390	+ .5584 ± .0621	−.2621 ± .0443	−9.2086 ± .4431	[−.1864 ± .2492]
<i>angusta</i> .....	−.8401 ± .1033	[+ .0798 ± .0534]	+3.5145 ± .3237	−.1906 ± .0608	+ .4564 ± .0422	+7.0503 ± .4322	+1.7644 ± .2362
<i>prima</i> .....	+ .4112 ± .1069	[−.0408 ± .0423]	−1.8067 ± .2866	+ .4405 ± .0538	[+ .0045 ± .0526]	−3.6552 ± .1479	+1.3936 ± .2189
<i>marmorata</i> :							
Southern .....	[−.2318 ± .1166]	[+ .0437 ± .0479]	+1.1456 ± .3071	[−.0060 ± .0593]	[+ .1221 ± .0558]	+1.1993 ± .1747	+ .9719 ± .2330
Taiarapu .....	[+ .1460 ± .1267]	[−.1256 ± .0628]	−1.3534 ± .3129	[−.0011 ± .0721]	[−.0687 ± .0512]	−.7372 ± .2224	[−.6300 ± .2594]
Eastern .....	[+ .3140 ± .1899]	+ .3400 ± .0983	[+ .9714 ± .5493]	[−.1142 ± .0848]	[+ .0472 ± .0655]	+1.7500 ± .2616	−2.2571 ± .2799
<i>prima</i> (?): (Papenoo) .....							

summaries, one result appears with great clearness, namely, the fact that a *local variety differs from the average to different degrees in different characters*. To illustrate by a single example, *P. clara angusta*, from Tereehia Valley, is far above the average in shell length, only slightly wider than the average, but decidedly below in proportions; the aperture is also much elongated, but the width falls greatly below the general average, and consequently the relative width of the aperture deviates excessively from the general condition. Comparing this colony with *prima* and *minor*,

its near neighbors, it will be seen that they also differ from the average to diverse degrees in the seven characters, and that the general course of deviation followed by one valley colony is independent of the mode pursued by another community.

IV. *The recent wide dispersal of clara seems to be the result of spontaneous active migration, and not of human transportation.* The question as to the mode of dispersal has already been discussed in the case of *marmorata*, and little needs to be added. In spreading toward the west and north, this species has come to occupy valleys whose mouths are more than 10 miles from the opening of Tereehia Valley, which was probably the western limit in Garrett's time; but the distance over the intervening ridges is far less. The migration into valleys of the eastern quadrant also involves a much shorter distance than the coastal arc of the eastern section beyond Maara and Apirimaue. To populate Tairapu, however, the snails must have followed the low vegetation across the isthmus until the higher and more humid mountains were gained and traversed to the further sides. The passage of the ridge between Vaihiria (or Taharua) and the great basin of Papenoo Valley necessitates a journey of only a mile or so. That the varieties of *clara* occurring in Papenoo are probably members of the *prima* series has already been shown.

It is quite true that the snails of this and other species occur on plants that are sometimes transported by man. The fruit of the wild plantain (fei) of the interior regions is continually sought by the natives as a staple article of food. But the man goes into that valley which is nearest to his home, and any snails hidden in a bunch of plantains brought to the coast would undoubtedly die before they could return from the dry shore areas to the moist woods—if, indeed, they were not roasted along with the fruit. Very rarely plantains are taken from one valley for establishment, and only in such cases would there be a chance of passive dispersal of a species. One such instance has actually been discovered in the smaller island of Moorea. In Tahiti, however, very little transplanting has been done, and in such cases the distance involved is very short, owing to the sectional animosities of the local tribes. To take a concrete case, the small forms called *minor* and *parva* occur in a region whose natives are somewhat at odds with those of the original area where *prima* now occurs. It is not probable that the former types have been established in the districts of Punaauia and Paea through the carriage of Papara shells on vegetable foods.

V. *Mutation has taken place in some, but not in all, of the localities into which clara has migrated recently; but mutation is shown as well in parts of the former territory of occupation.* The first point is sufficiently established by the paragraphs in the foregoing detailed description that deals with the banded types of Aoua and other valleys, and with the form-varieties in places occupied by var. *marmorata*. Only in the first-named cases, however, can the final criterion of mutation be employed, where the banded aberrant can be proved to produce similar banded offspring; in the case of *marmorata*, the mutants of large size can be designated as such with finality only when their young may be reared to a point where the parental charac-

TABLE 31. *Partula clara*. Progressive varia  
primary varieties as regards range and av  
The interrupted line represents the general

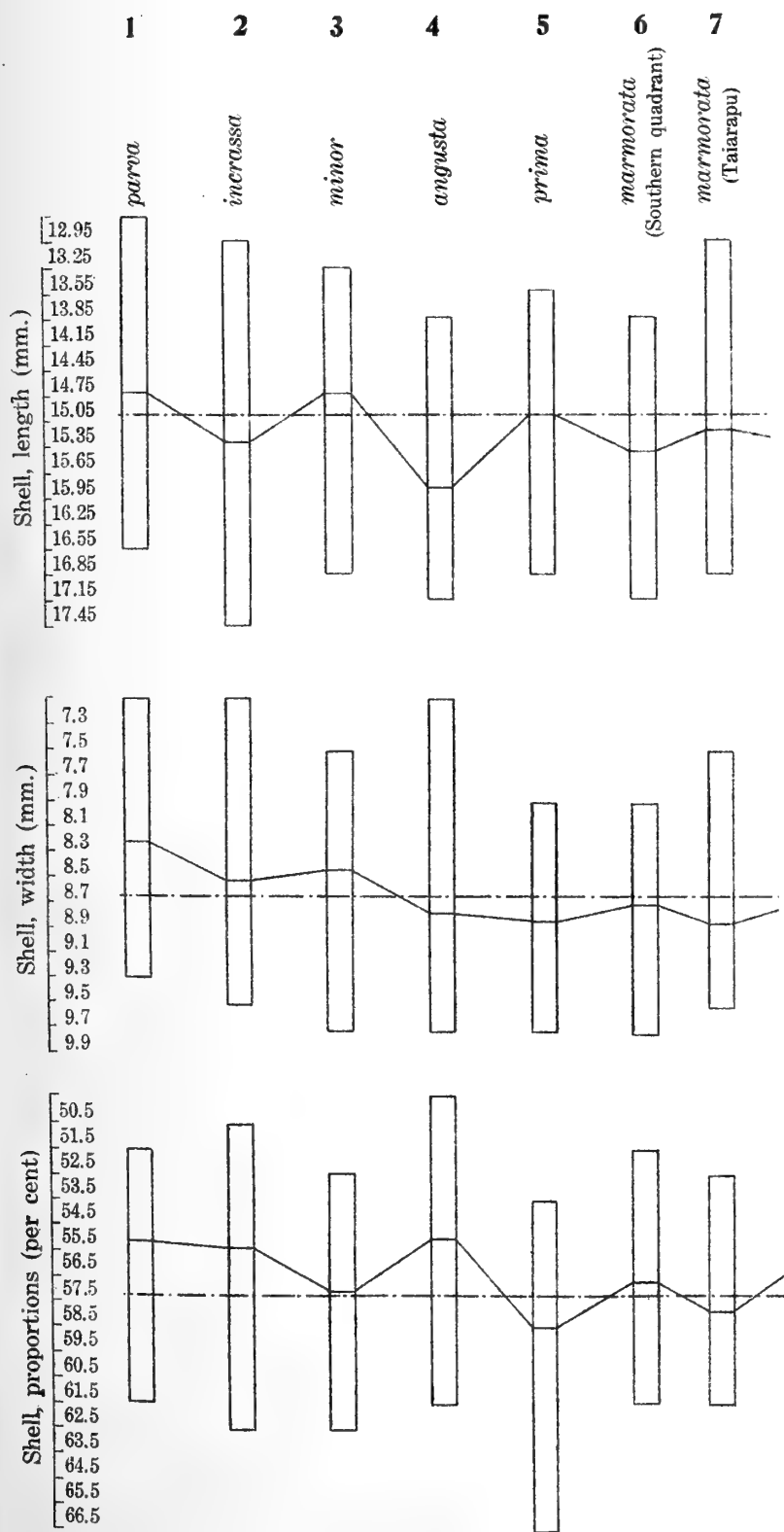
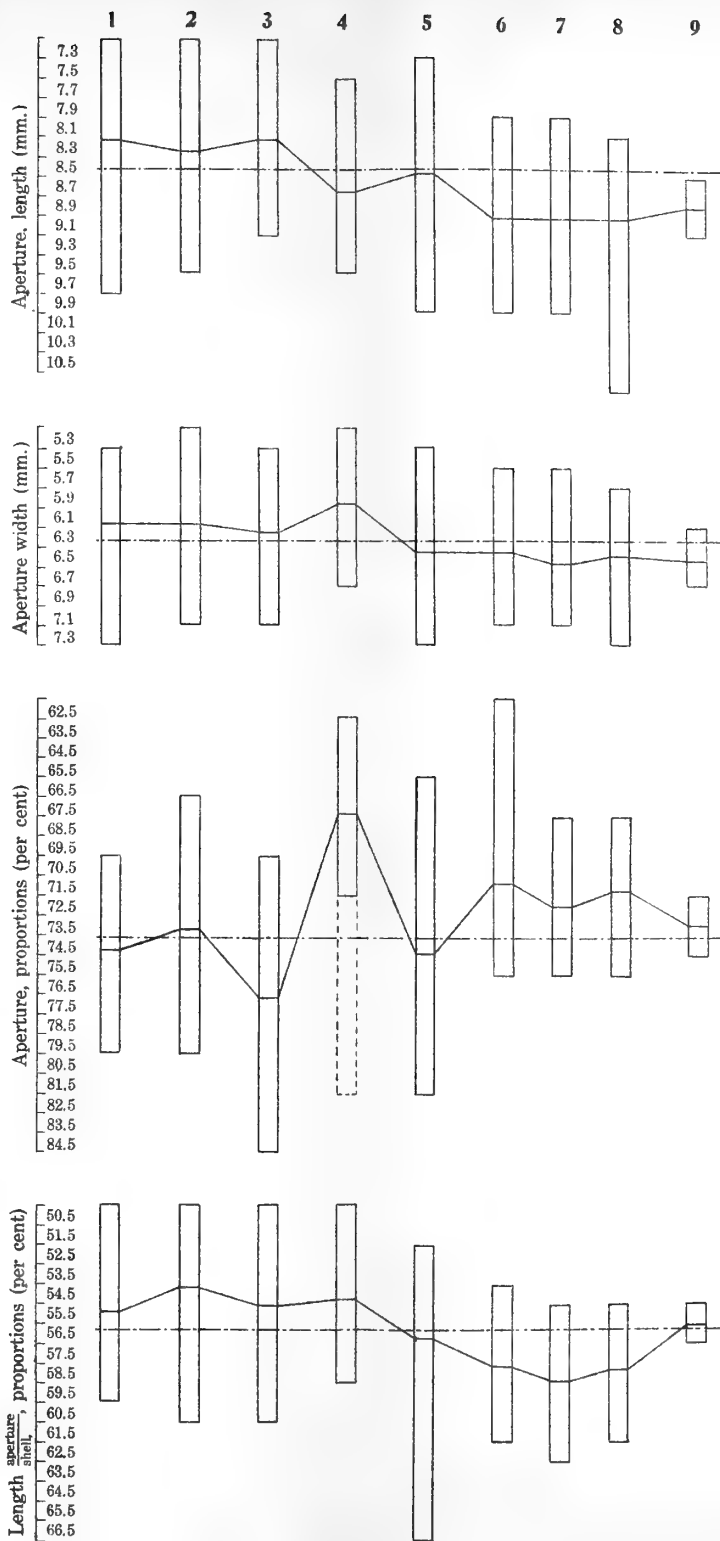
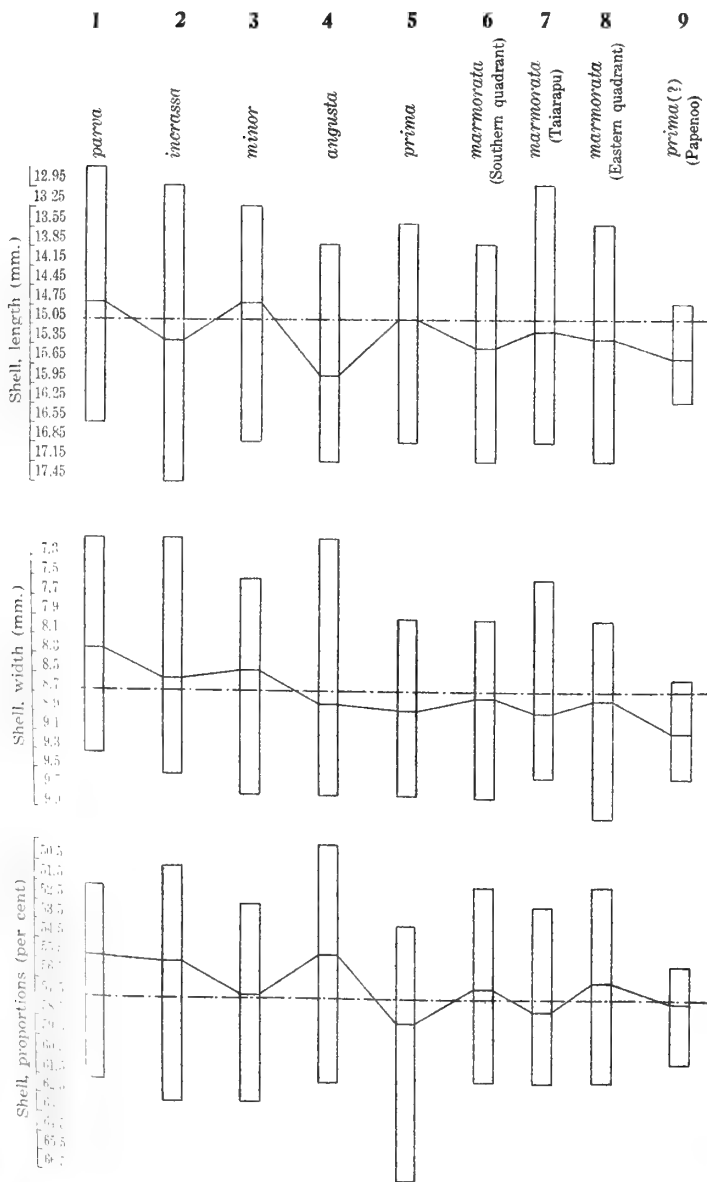




TABLE 31. *Partula clara*. Progressive variation of the primary varieties as regards range and average value. The interrupted line represents the general average.







ter may be recognized. It is significant, none the less, that the various colonies of *marmorata* differ so greatly, in localities which have been recently occupied by migrants from the old territory.

But it is not justifiable to conclude that mutation can take place, or has taken place, only when a new locality is invaded. In several of the valleys originally inhabited by var. *prima*, banded forms occur that are peculiar, although of course they all agree in having the rotating stripes. The shells of Faarahi and Vaihiria (plate 21, figs. 13, 14, and 19 to 23) are sufficient to illustrate this point. Aside from the fact that ecological conditions are essentially similar in all parts of the island, wherefore it would be difficult or impossible to distinguish the environmental factors producing mutation when a species like *clara* emigrates to a new locality, it is significant that, under the conditions persisting in an old habitat, slight mutations may occur.

VI. *Partula clara* must not be regarded as a newly arisen species, but as one which has recently revived after a long period of racial decline. Its nearest relatives are *P. hyalina* (of its own island and other groups), *P. attenuata* (of Tahiti and Raiatea), and *P. annectens* (of Huahine). This congeries of forms is widely spread, and its members depart in their individual ways only slightly from the common qualities of all. While *P. clara* might have originated from *P. attenuata* in Tahiti, and not in Raiatea, this does not seem probable, because the latter species is narrowly restricted in its variations; *P. hyalina* is colorless and could scarcely have given rise to the colored varieties of *P. clara*.

The general impression that deepens in the course of close studies like the foregoing has been well expressed by Pilsbry, in writing about the group including the four species enumerated, including *Partula clara*. He says (p. 179):

"These forms may have exceptional means of distribution, or they may be conservative stocks, which have altered little since the original radiation over the mountain ranges which are now islands. They approach the simply colored southwestern forms of *Partula*, such as those of the Solomon Islands, in appearance, and seem to be little changed members of an old stock."

There are no exceptional means of distribution at the service of these species; as for the rest, my own conclusions are in entire accord with those of Pilsbry. It is clear that in recent years *Partula clara* has entered upon a new period of vigorous increase, dispersal, and differentiation, after its long history of quiet, toward the end of which it seems to have been in imminent danger of extinction.



## CHAPTER V.

### PARTULA FILOSA Pfeiffer.

#### GENERAL CONSIDERATIONS.

*Partula filosa* is a small dextral species that exists solely in Pirai Valley, a large topographical element of the second grade of size, situated in the drier northwestern part of Tahiti nui. Its sharp restriction in habitat is a feature shared with only two or three others of the three score species of the genus living in the Society Islands, and places *filosa* at the opposite extreme from *hyalina*, whose range extends not only throughout Tahiti but also to islands of two other groups as well. Notwithstanding its occurrence in only one valley, *filosa* displays a variability which in certain respects exceeds that of some species inhabiting several separated but neighboring valleys of a large island sector. This species is clearly distinguishable from all others of its island; only Reeve has confused it with another form—an abbreviated variety of *P. otaheitana*.

Pfeiffer's original description (Proc. Zool. Soc., 1851), translated in Pilsbry, is as follows:

"Shell perforate, conic-ovate, solid, sculptured with impressed spiral lines, hardly shining; chestnut-colored, ornamented with ashen hair-lines. Spire conic, rather obtuse. Whorls 5, flattened, the last as long as the spire, more convex, columella slightly plicate above. Aperture a little oblique, sub-triangular-semioval; peristome a little expanded, provided with a thick prominent callus within. Length 16, diam.  $8\frac{1}{2}$  mm. long,  $6\frac{1}{2}$  wide. Hab. Navigators Islands."

The locality given is erroneous, for neither *filosa* nor any similar species occurs in the group mentioned, which is now called the Samoan Islands.

Pease's description of this species as *P. lineolata* (Amer. Journ. Conch., 1867) adds nothing essential to that of Pfeiffer; his shells were dark examples like the earlier author's types, but he speaks of "*var.* pale straw color or light reddish brown." He gives the correct locality, Tahiti, and expresses the opinion that *lineolata* is "allied to *P. filosa* Pfr., inhabiting the Samoan Islands." As a matter of fact, *filosa* and *lineolata* are identical.

Garrett (1884) comments as follows:

"This small and well-characterized species is restricted to the lower portion of Pirai Valley, on the northwest coast of Tahiti, where it is abundant on foliage. . . . It is a solid, ovate-conic, chestnut-colored shell, marked by longitudinal cinereous strigations, and constant tuberculiform parietal tooth. The aperture is rather small, semi-oval, considerably contracted by the white, convex outer lip. It is never encircled by bands. Examples of a pale straw or flesh tint are not infrequent."

Mayer (1898) also found *filosa* in Pirai Valley, where it formed 17.6 per cent of his collection of 164 snails, a figure that is not far from my own number of 16.8 per cent out of a total series of 1,254 adult individuals. Mayer adds certain important observations on the color relations of embryonic snails to those of their parents.

In the collections of the present research, *filosa* is represented by 211 adults of various colors, about 40 adolescent snails, and more than 60 embryonic young and eggs taken from the gravid full-grown individuals. In each of the four years of field-work, material was obtained from Pirai. On account of the havoc wrought by the cyclone of 1906, it was possible to penetrate only a short distance into the valley in that year, when 52 *filosa* out of 371 adults were secured (14 per cent). In 1907 a total series of 295 adult Partulæ was obtained from the intermediate valley, of which only 24 (8.13 per cent) were *filosa*. The following year a small collection was made again from the middle portion of the inhabited area, in which this species amounted to 11.2 per cent. Finally in 1909 a journey was made to very near the limit of occupation toward the higher part of the valley; at that time, 123 adult *filosa* were obtained and these constituted 25.1 per cent of the series that was preserved. But 400 to 500 other snails representing *P. otaheitana* were also taken, to be immediately returned to their environment; hence the frequency of *filosa* is really about half of the indicated percentage for the year. It is clear that this species is not *restricted* to the lower part of Pirai Valley, although it is true that it exists in relatively greater numbers in the lower levels. It appears also that statistical differences are brought to light when the collections of different portions of the inhabited regions are analyzed in detail, as described beyond.

The single valley inhabited by *filosa* lies on the northwestern side of Tahiti nui, almost at the exact center of the leeward slopes of the whole mountain mass (cf. plates 5a, 9, 10, and 11). In the sector which is bounded by Fautaua Valley on the west and Papenoo Valley on the east, the land rises to the highest peaks of the island, Mounts Orohena and Aorai. The seaward side of this sector is deeply cut by Pirai to the west of Point Venus and by Ahonu and Tuauru Valleys to the east of this cape, all of which are of the second order of size. Other valleys and gullies of lesser depth and extent also occur here, but on the whole this sector forms a relatively compact triangular land-mass. The depression of Pirai Valley itself is gradually lost in the heights, so that it does not communicate with either Fautaua or Papenoo.

The flat plain of the coastal shelf runs well up into the valley, where wide cane fields and coconut groves occupy the level or nearly level floor. Along the lower slopes of the bordering ridges and along the stream there are dense thickets of hibiscus and guava trees. About 1.5 miles from the coast the valley narrows suddenly, the sides become more precipitous, and the succulent vegetation of the shaded and moist interior regions is met with.

The first snails were found a little more than 2 miles inland, at an altitude of 375 feet, on the plantain (fei), *Dracæna* (ti), ginger (opui), turmeric, and birds-nest fern (oaha). A few were obtained from wild pineapples and *Pandanus*.

In 1909 I found extensive changes in this part of the valley, owing to the development of vanilla plantations, as the result of which the undergrowth had been much reduced, so that the whole lower region was rendered practically uninhabitable for Partulæ.

Higher up, the plantains become more numerous, and thick growths of the caladium ('ape) occur, especially in the steep pocket-like ravines along the walls of



A. The vegetation of a typical locality for *Partula filosa*, about three miles up Pirai Valley.



B. The inner part of Pirai Valley, and its vegetation, from a point about 100 ft. above the level of the stream. Beyond this place very few *Partulae* are to be found.



the main valley cutting (plate 18a). At 550 feet altitude, about 3.5 miles from the shore, the valley trends suddenly to the east, then to the west, and the stream-bed rises more rapidly. As a result this part is more open, although its sides are covered by dense vegetation, owing to the great amount of rain that falls upon these interior heights (plate 18b). Nevertheless, the snails are few in number and exist only a short distance beyond.

The food-habits of *filosa*, and indeed all of its ecological relations, are in no wise peculiar. The snails are less sensitive to day-time changes in moisture than are *hyalina* and *clara*, for only the younger immature individuals become active after a shower of rain, so far as observations have been made.

#### THE SHELL OF PARTULA FILOSA AND ITS VARIATION.

Though this species inhabits only a single valley, the range of its color-variation is greater than in the case of the widespread unbanded varieties of *clara*. In addition, the shells of the upper and lower portions of the valley differ as much in structural respects as do many of the neighboring but separated valley colonies of *clara* and *hyalina*. In brief, this species is far from being invariable, even though it is so sharply restricted geographically.

TABLE 32.—*Partula filosa*. Pirai Valley.

MEAN VALUE.								
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.	
Whole valley (all years)	209	<i>mm.</i> 14.1572 ± .0295	<i>mm.</i> 9.1029 ± .0161	<i>p. ct.</i> 64.2751 ± .1029	<i>mm.</i> 7.6292 ± .0182	<i>mm.</i> 6.4541 ± .0151	<i>p. ct.</i> 84.4761 ± .1489	<i>p. ct.</i> 53.7536 ± .0838
Upper valley (1909)...	122	13.9754 ± .0337	9.0262 ± .0193	64.5410 ± .1279	7.5311 ± .0200	6.3738 ± .0192	84.5902 ± .1902	53.7213 ± .1083
Lower valley (1906)...	52	14.4904 ± .0581	9.2654 ± .0339	63.9115 ± .2046	7.8423 ± .0404	6.6615 ± .0279	84.8269 ± .3284	53.9615 ± .1838
Difference, 1906:1909..	...	+ .5150 ± .0671	+ .2392 ± .0390	[ - .6295 ± .2413]	+ .3112 ± .0451	+ .2877 ± .0339	[ + .2367 ± .3795]	[ + .2402 ± .2133]
STANDARD DEVIATION.								
Whole valley (all years)	209	0.6338 ± .0209	0.3452 ± .0114	2.2074 ± .0728	0.3913 ± .0129	0.3241 ± .0107	3.1945 ± .1054	1.7978 ± .0593
Upper valley (1909)...	122	.5524 ± .0239	.3159 ± .0136	2.0936 ± .0904	.3279 ± .0142	.3138 ± .0136	3.1126 ± .1345	1.7718 ± .0765
Lower valley (1906)...	52	.6213 ± .0411	.3631 ± .0240	2.1879 ± .1446	.4320 ± .0286	.2988 ± .0196	3.5121 ± .2321	1.9656 ± .1299
Difference, 1906:1909..	...	[ + .0689 ± .0475]	[ + .0472 ± .0276]	[ + .0943 ± .1705]	+ .1041 ± .0319	[ - .0150 ± .0239]	[ + .3995 ± .2682]	[ + .1938 ± .1889]

Considering first the structural characters of the shells and their variation, we may add to the qualitative descriptions of earlier authors the precise statistical determinations of the whole measurable series of adult shells (table 32). In the next place, we may compare the shells taken from the upper part of the range in 1909 with those obtained in 1906 from the lower areas, with the result that marked differences are brought to light which are demonstrated both by the statistics (table 32) and the graphic representations of table 33. Specifically, the lower association consists of shells that are longer and wider, but narrower, with probability even if not with statistical certainty. The apertures are also longer and wider

than in the more inland group, but the proportionate measures are not distinctively different. As regards variability, the two series prove to be similar in all of the characters, excepting only in length of the aperture, in which respect the coastward shells prove to be less consistent.

Classified according to color, the shells fall into five well-marked divisions, as follows:

*Class A* (plate 21, figs. 32 to 34) comprises only a few individuals—3.27 per cent of the 1909 series—which have a shell that is almost white, marked with yellowish strigations across the whorls. The apex is clear and untinted.

*Class B* (plate 21, figs. 35 and 36) is characterized by a deeper yellowish or terra-cotta color and a light ruddy purple or purplish-brown apex. These number 5.73 per cent of the whole series.

*Class C* (plate 21, figs. 37 to 41) includes 32.78 per cent of the representative collections, whose shells are ruddy brown or yellowish brown, with an apex of the same shade or of an intensified and deeper tint. Sometimes the shell is almost uniform in color, owing to the indistinctness of the transverse ashy streaks (fig. 41).

*Class D* (plate 21, fig. 42; plate 22, figs. 1 to 4) amounting to 26.22 per cent, is made up of brown shells with deep brownish strigations. These have very little of the ruddy tinge which appears in the specimens assigned to Classes B and C. Now and again some of the shells exhibit a nearly uniform coloration (fig. 4).

*Class E* (plate 22, figs. 5 to 8) is distinguished by a very dark purple-brown color and deeply tinted apex. It comprises 31.96 per cent of the 1909 series.

TABLE 34.—*Partula filosa*. Statistical comparison of the color-classes, 1909 series.

MEAN VALUE.								
Class.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.	
		<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>p. ct.</i>
A, very light. . . .	4	14.0750 ± .0839	9.2000 ± .1012	65.2500 ± .3674	7.5000 ± .0477	6.5000 ± .0477	86.5000 ± .3372	53.5000 ± .2384
B, yellowish. . . .	7	13.9358 ± .0888	8.9572 ± .0525	64.6428 ± .5686	7.6714 ± .0425	6.4715 ± .0635	84.3572 ± .9383	55.0714 ± .3886
C, reddish-brown. .	40	14.0075 ± .0647	9.0200 ± .0375	64.2750 ± .2178	7.5500 ± .0389	6.4300 ± .0365	84.9750 ± .3286	53.7000 ± .1434
D, brown. . . . .	32	13.8875 ± .0678	9.0500 ± .0347	65.2187 ± .2370	7.4750 ± .0236	6.2938 ± .0375	84.1875 ± .3774	53.6562 ± .2495
E, purple-brown. .	39	14.0116 ± .0643	9.0079 ± .0331	64.1667 ± .2299	7.5359 ± .0423	6.3513 ± .0308	84.3718 ± .3255	53.5769 ± .2137
All. . . . .	122	13.9754 ± .0337	9.0262 ± .0193	64.5410 ± .1279	7.5311 ± .0200	6.3738 ± .0192	84.5902 ± .1902	53.7213 ± .1083
STANDARD DEVIATION.								
A, very light. . . .	4	0.2487 ± .0593	0.3000 ± .0716	1.0897 ± .2599	0.1414 ± .0337	0.1414 ± .0337	1.0000 ± .2385	0.7071 ± .1686
B, yellowish. . . .	7	.3482 ± .0628	.2060 ± .0371	2.2307 ± .4022	.1666 ± .0300	.2490 ± .0449	3.6811 ± .6637	1.5245 ± .2749
C, reddish-brown. .	40	.6074 ± .0458	.3515 ± .0265	2.0431 ± .1540	.3653 ± .0275	.3421 ± .0258	3.0821 ± .2324	1.3453 ± .1014
D, brown. . . . .	32	.5688 ± .0480	.2915 ± .0246	1.9880 ± .1678	.1984 ± .0167	.3142 ± .0265	3.1665 ± .2673	2.0933 ± .1767
E, purple-brown. .	39	.5955 ± .0455	.3067 ± .0234	2.1283 ± .1626	.3918 ± .0299	.2854 ± .0218	3.0143 ± .2303	1.9791 ± .1512
All. . . . .	122	.5524 ± .0239	.3159 ± .0136	2.0936 ± .0904	.3279 ± .0142	.3138 ± .0136	3.1126 ± .1345	1.7718 ± .0765

Turning now to the measurable characters of the five color-classes, it appears from the statistics of the longer 1909 series (table 34) that they differ somewhat, like isolated colonies of other species existing in neighboring valleys, or like the contrasted color-types of *clara* living in one valley, such as *Vaihiria*. Furthermore,



TABLE 33. *Parti*  
of 1909 serie  
groups.

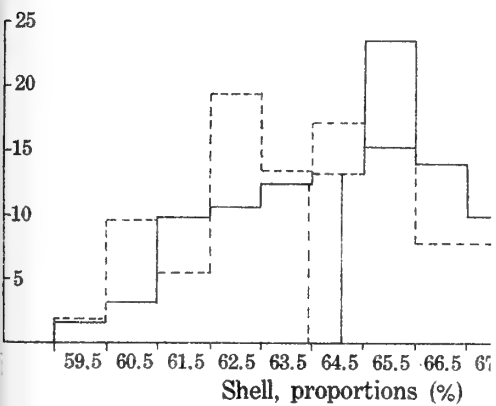
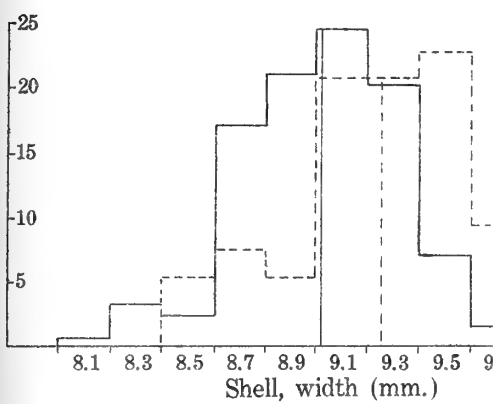
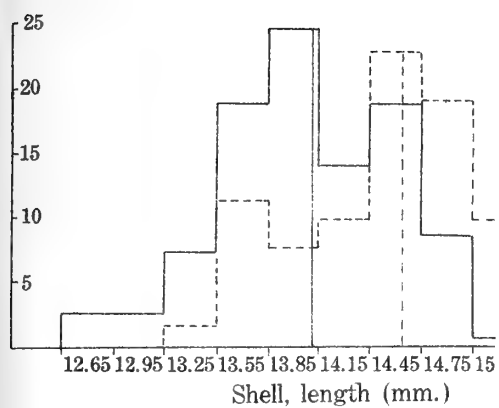
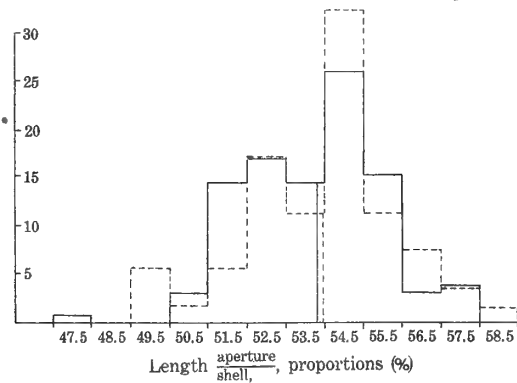
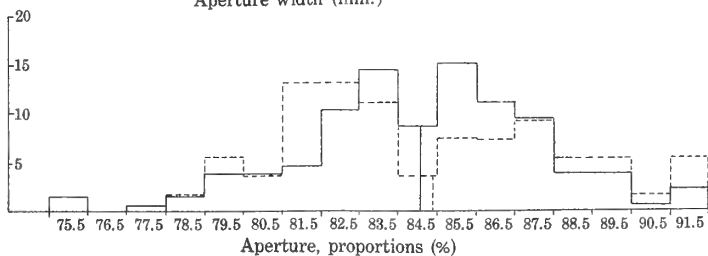
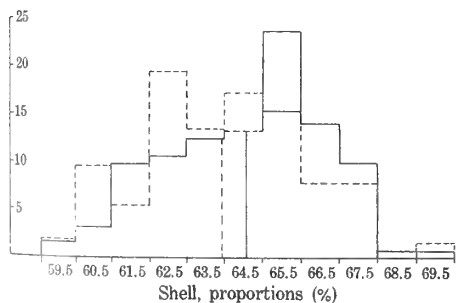
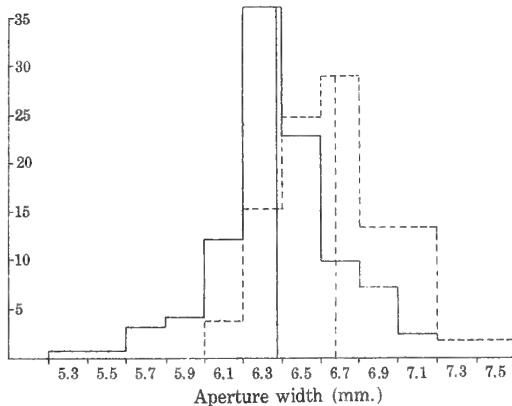
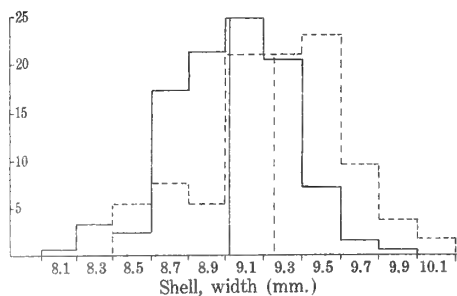
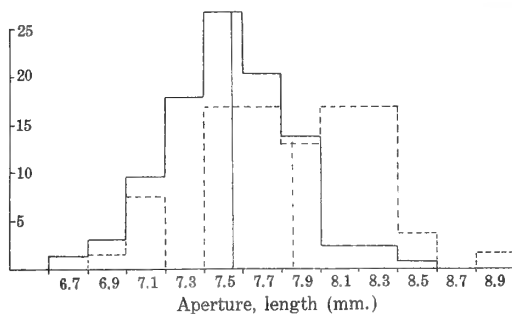
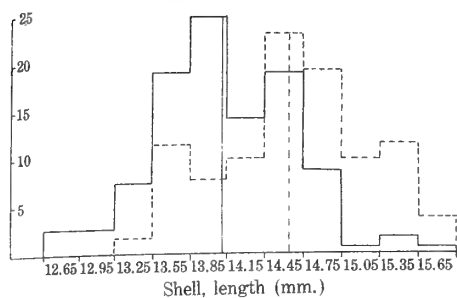




TABLE 33. *Partula filosa*. Polygons of variation of 1906 series (broken lines) and of 1909 series (full lines). Frequencies in percentages of the comparable groups.





the shells of one class depart widely from the average in one character and not in others, while a second class deviates in the latter more than in the former. The figures relating to C, D, and E are particularly significant in this connection.

#### FECUNDITY AND HEREDITY.

Many of the snails were kept alive for several months for the study of their habits and their responses to environmental influences. Hence the numbers of complete records of fecundity is reduced to 117 (55 per cent). Of this number, 76 (64.9 per cent) were gravid. The numbers of eggs and young borne by these individuals are given in table 35. The series of 1909, taken during a somewhat drier period of the year, shows a low percentage of fecundity, while that of 1906 gives a relatively high value for the wetter season. Apparently, then, external influences, such as moisture, temperature, etc., exert an influence upon the time of breeding in this instance which they do not have in the cases of the widely spread *clara* and *hyalina*.

The general average for both series is 1.16 per cent of eggs and young for all adults, and 1.63 per cent for the gravid snails. These figures are far below the average for *hyalina* and *clara* and also somewhat below the percentage for *otaheitana*. Either *filosa* is not subject to severe eliminative influences, so that the low birth-rate is sufficient to keep the species alive, or else it is in imminent danger of extinction. The former supposition seems more probable.

TABLE 35.—*Partula filosa*. Fecundity.

Series.	Records.	No. gravid.	Percent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.
1906	20	15	75.0	17	17	34	2.26	1.70
1909	97	61	62.9	34	27	61	1.00	0.63

TABLE 36.—*Partula filosa*. Pirai Valley. Heredity of color.

Color classes of parents.	Lower valley (1906).						Upper valley (1909).					
	Classes of young.					Total.	Classes of young.					Total.
	A	B	C	D	E		A	B	C	D	E	
A.....	..	..	..	..	..	..	1	2	1	..	..	4
B.....	..	..	..	..	..	..	..	4	..	..	..	4
C.....	..	2	2	1	..	5	..	1	10	3	..	14
D.....	..	..	5	2	..	7	..	1	4	3	..	8
E.....	..	..	1	2	..	3	..	..	1	1	2	4
Total...	..	2	8	5	..	15	1	8	16	7	2	34

The unborn snails possess shells which are usually colored like those of the parent, but this is not invariably the case, for they sometimes belong to a lighter or to a darker class than their parents. The statistics are given in table 36. It is interesting to find that when two well-advanced young are present, they usually belong to the same color-class, but sometimes they differ; in such rare cases one of them is like the parent, while the other belongs to a color-group only one degree

removed in the lighter or darker direction. The collection from the lower valley, taken in 1906, is not essentially different from the series of the upper valley, obtained in 1909, as regards the relative numbers representing the several color divisions.

#### SUMMARY AND CONCLUSION.

The noteworthy feature of distribution is the rigid confinement of *filosa* to a single valley of Tahiti, Pirai. Notwithstanding this restriction, the shells of this species exhibit a remarkable degree of variation in color and in form.

The dryness of the northwestern section, in which Pirai Valley lies, accounts for the inability of the Pirai colony to send migrants into adjacent and equally suitable regions.

We may view this single valley association of *filosa* as the sole relic of a form or series of forms that in earlier times possessed a far wider range, but whose representatives in other localities of Tahiti have disappeared on account of their constitutional inability to maintain themselves; the only other form of Tahiti that is allied to *filosa* is *P. nodosa*—a somewhat distant connection. In other islands of the group, relatives of *filosa* are to be found that have evolved from the same ancestral stock along other lines of modification.

## CHAPTER VI.

### PARTULA NODOSA Pfeiffer.

#### GENERAL CONSIDERATIONS.

Seven valleys of the western quadrant of Tahiti nui, situated in the districts of Punaauia and Paea, are inhabited by the beautiful species that was named *Partula nodosa* by Pfeiffer in 1851, on account of the nodular columella. In Garrett's report of his careful field-studies, *nodosa* was described as occurring in Punaruu Valley only, but Mayer secured some noteworthy reversed shells of the same species in Maruapoo Valley, which is a small ravine immediately adjoining Punaruu to the south. In the course of the present research, *P. nodosa* has been taken from a series of seven areas, including the above, and in each of these it displays a number of characteristics that are peculiar to the colony of that particular locality.

This species differs from *P. hyalina* and *P. clara* in its restriction to a compact sector, which, however, is not so contracted as the area inhabited by *P. filosa*. Its numbers are greater in nearly every valley of its range, in which respect *nodosa* resembles *P. otaheitana*; and in its differentiation within the borders of its field of occupation it also resembles the series of *otaheitana* colonies existing in the same or in a similar series of valleys. Despite the narrow range and the relatively small number of colonies, the data at hand afford trustworthy evidence of recent migration into one or more valleys previously unpopulated, and equally clear indication that a certain amount of mutation has taken place in recent years.

Pfeiffer's original description is as follows:

"Shell perforate, conic ovate, rather solid, obsoletely decussate; chestnut-colored, ornamented with a wide white band at the suture, and often some other pale bands. Spire conic, acute. Whorls  $5\frac{1}{2}$ , a little flattened, the last about as long as the spire. Columella plicate above, deep within, then nodulose. Aperture subvertical, oblong, narrow; peristome outwardly scarcely expanded; inwardly provided with an acutely projecting white callus, contracting the aperture; margins subparallel, the right margin a little straightened. Length 16, diam. 8, aperture 6 long inside, 4 wide."

Pease, in 1866, described the ornamented shells of this species as *Partula trilineata*, which is subsequently (1871) made var. *trilineata* of Pfeiffer's species. His description reads:

"Cream color or yellowish horn-color, the spire usually reddish-brown, last whorl striped irregularly with brown, and encircled by three dark reddish-brown lines or bands; suture margined with white."

In 1899, Mayer explored Maruapoo Valley, where he found a colony of *nodosa* made up mainly (94 per cent) of reversed individuals. To this group he gave the distinctive name of var. *sinistralis*. Pilsbry points out the prior use of this term for another type of *Partula*, and substitutes var. *laeva* for Mayer's designation.

The descriptions in the literature and the early collections now in various places specify and exemplify two classes of shells which differ in the direction of the spiral and four principal classes that are distinguishable on the basis of color characters.

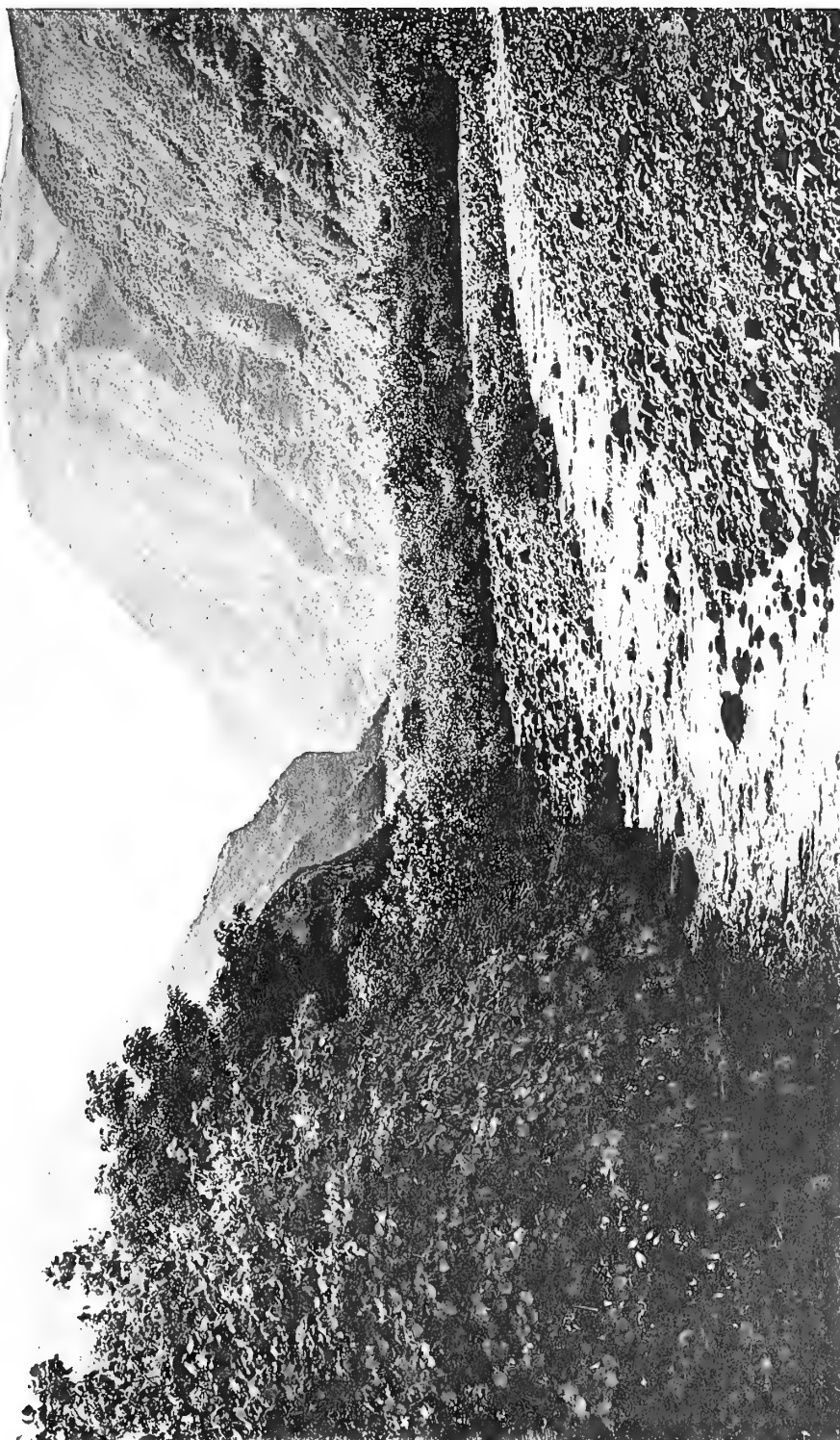
Shells of the dextral coil are regarded as more typical, save in the case of the colony termed var. *laeva*. The specimens which are viewed as typical in color are brown or otherwise dark-colored examples (see figs. 26 to 30, plate 22) devoid of brown bands, but marked by a white sutural area; they constitute what is really a color-class rather than a variety in the sense of a subspecies, and although some other term referring explicitly to their coloration might well be employed, yet on account of their earlier definition they will be treated in the present discussion as forming the color-class *nodosa*, orthographically distinguished from a taxonomic variety. All of the banded forms are assigned by earlier authors to var. *trilineata*, although but two bands or only one may be present (see figs. 11 to 21, plate 22); but this group also is only a color-class and not a subspecies in the proper sense, wherefore the term is to be written distinctively, as *trilineata*. Light flesh-colored shells without the bands are, by Pilsbry, properly distinguished as "color-form *pallidior*" (see figs. 9 and 10, plate 22). A special name has not been given to the color-type with a wide revolving zone, although it is as much entitled to independent status as any of the foregoing (see figs. 22 to 25, plate 22); it is herein called the color-form *concrescens*, because the broad zone is formed by the merging of two bands that are separate in *trilineata*.

The four color-classes are intimately related and without question belong to one stock which has undergone a considerable amount of differentiation in respect to color and color-pattern; nevertheless, they are not physiologically distinct and independent to the degree that is necessary for their designation as taxonomic *varieties*. In the course of the following detailed analysis of the several valley colonies, differential characteristics of the *nodosa* colonies will be demonstrated, which belong to a category quite independent of the color classification. All four divisions established on the latter basis may or may not be represented in a colony which, as a whole, differs from another in certain other respects. Whether or not the color differentiation is more basic than the geographical differentiation does not need to be settled here. In the present research, attention is directed primarily to differences exhibited by isolated colonial groups of one and the same species; and if the terminology is to be made an aid to the main purpose, the regional classification may be made paramount, as in the case of *P. clara*, while the color classification may be, and hereafter is, to be used, if at all, for the practical purposes of precise description. The biological points involved will receive due attention in the concluding part of this section.

#### THE GEOGRAPHICAL DISTRIBUTION OF PARTULA NODOSA.

This species inhabits seven valleys lying in the western quadrant of Tahiti nui, which form a consecutive series beginning with Taapuna at the north and ending with Orofere at the south. The range of this species is therefore continuous and not interrupted, as are the ranges of *P. clara* and *P. hyalina*. In order to understand the significant features of the distribution in the case of *P. nodosa* a full description of the area of its occurrence is essential.





The lower portions of Punaruu Valley looking inland from a height near the shore.



Punaruu Valley—sometimes called Punaauia, from the district in which it is so conspicuous a feature—is one of the few primary valleys in order of size (see plates 12 and 19). Its mouth is wide, and it remains relatively open in its inland extension. About 8 miles from the coast its floor rises more rapidly to a so-called “plateau,” beyond which the valley opens out into the crater-like basin of its commencement or “head.” Sharp-cut boundaries with precipitous walls separate this part from the beginnings of Fautaua and Temarua Valleys and from the great central basin of Papenoo. The land-mass between Punaruu and Fautaua is cut on its western slope by Taapuna Valley, one of the second order in size, and by several shallow but long gullies that prove to be unfavorable habitations for *Partula*. The greater mountain mass lying south of Punaruu, between it and Temarua, is divided by Orofere Valley, an element of the second order. Between the latter and the former the massif is cut by two valleys of the third order, Aoua and Papehue (see plate 15*b*), and by a few deep but short and narrow gorges, such as Atehi and Maruapoo. The above-mentioned geographical and topographical details must be taken into full account in dealing with the relationships of the various colonies of *P. nodosa* found in the valleys of this quadrant of the island.

The material of the present investigation comprises 1,922 adults and 484 partly grown individuals; the former amount to 7.98 per cent of the mature population of the entire island, and to 42.78 per cent of the 4,492 adults obtained in the seven valleys where *nodosa* occurs. The adolescents of this species amount to 47.5 per cent of the number taken in the same range. The absolute and relative members of *nodosa* in the several valleys are given in table 37, together with the numbers of dextral and sinistral individuals in each locality.

TABLE 37.—*Partula nodosa*. Frequency and distribution.

Valley.	No. of adult <i>nodosa</i> .	Percentage of adult population.	Dextral.		Sinistral.		Variety.
			No.	Per cent.	No.	Per cent.	
Taapuna.....	313	56.80	306	97.7	7	2.2	} <i>composita</i> . <i>lava</i> . <i>exigua</i> .
Punaruu.....	186	24.60	186	....	0	....	
Maruapoo.....	795	84.12	28	3.5	767	96.4	
Atehi.....	4	0.89	4	....	0	....	} <i>intermedia</i> .
Papehue.....	210	53.57	210	....	0	....	
Aoua.....	396	34.98	396	....	0	....	
Orofere.....	18	6.77	18	....	0	....	
Total.....	1,922	{ <sup>1</sup> 42.79 <sup>2</sup> 37.39	{ 1,148	....	774	....	

<sup>1</sup>Actual.<sup>2</sup>Average.

Garrett's circumstantial account of his observations on *nodosa* is sufficiently important to be quoted at length. He says:

“This beautiful arboreal species is restricted to a limited area about two miles up Punaauia Valley on the west coast of Tahiti. I first discovered the location in 1861, and gathered about three hundred examples. On a subsequent visit, nine years later, I secured over eight hundred specimens. It is *entirely* confined to the south side of the stream which flows through the valley, and circumscribed in a narrow area three-quarters of a mile in length. When Mr. Pease described his *trilineata* he gave the correct locality; but, in his

list of Polynesian land-shells, he wrongly assigns it to Moorea. Dr. Pfeiffer gives Tahiti and the Navigator Islands as its habitat. The type is purely Tahitian and does not occur at the latter group. . . . About one in two hundred is sinistral. Bandless varieties are not infrequent, and some are fulvous or light chestnut brown, with a pale narrow sutural band."

The first point of importance is that the range of *P. nodosa* is now far wider than it seemed to be in Garrett's time. This may signify a recent spread of the species or it may mean only that Garrett confined his explorations in the western quadrant to Punaruu Valley, designated by the name of its district. Both suppositions are correct, in my opinion. Probably Garrett did not explore fully the smaller gorges adjacent to Punaruu, like Maruapoo and Atehi; and it is possible that he gave little attention to Taapuna on the north, or to Papehue and Aoua to the south, for he does not mention these localities specifically. But it is certain that he studied the snails of Orofere, for he correctly described the varieties of *P. otaheitana* existing in that valley, which he designated by a now obsolete name. Furthermore, *nodosa* was not taken by me in 1907 in Orofere Valley, while in the following year I found a few individuals *in exactly the same locality* which was visited earlier. Hence it is fair to conclude that *P. nodosa* has spread recently from a small area of former occupation, although this may not have been as restricted in Garrett's time as that investigator supposed.

Considering now the varying frequency of this species in the different valleys of its territory, a striking feature is the small collection from Atehi, 4 out of 450 adults. This can not be due solely to the small size of the valley in question, for Maruapoo is almost as small, but 84 per cent of its 945 adults belonged to *nodosa*. Again, the abundance of *P. otaheitana* in Atehi proves that it is a favorable habitat for Partulæ. It does not seem likely that the species has only recently established itself here, an explanation which must be adopted for the small numbers in Orofere; it would seem rather that *P. nodosa* was formerly more abundant in Atehi and that it had decreased in numbers and relative frequency, owing to inherent weakness, as in the case of many colonies of *P. hyalina* and *P. clara*.

The next general point of note is that sinistral adult snails occur in collections from Taapuna and Maruapoo and that they far outnumber the dextral individuals in the latter instance. For one reason and another, a larger series could not be secured in Punaruu; and as Garrett states that only 1 in 200 from this valley was sinistral in his time, the non-occurrence of such shells in my collection of 290 individuals of all ages can not be regarded as satisfactory evidence of their complete absence from this valley at present; certainly, however, the reversed type has not increased in relative numbers during recent decades.

#### THE REGIONAL VARIATION OF THE SHELL OF PARTULA NODOSA.

Passing now to the detailed description of the species, we will take up the several colonies, valley by valley, in order to distinguish the collective characteristics that give the peculiar complexion to the group of each locality. The distinctive colonial character in any instance is determined by (1) the proportionate numbers of this species in the population of the valley, a matter duly noted earlier; (2) the propor-

tionate numbers of dextral and sinistral snails, when the latter are present; (3) by the relative numbers of either mode of coil that are assignable to the several color-classes; (4) by additional peculiarities in the matter of size, etc., that may be even more fundamental than the other differentia.

On the basis of the above, four regional varieties will be established, to be distinguished for practical purposes by proper names. The first, var. *composita*, includes the shells of Garrett's classical area, Punaruu, as well as those of Taapuna; the second, var. *læva* [(Mayer) Pilsbry] occurs in Maruapoo; the third, *exigua*, occupies Atehi Valley only; the fourth, derived from the first and now inhabiting Papehūe, Aoua, and Orofere Valleys, is genetically transitional from the first-named to the third, and may be termed *intermedia*. These varieties will be described in the above-stated order, and the Taapuna colony will be taken up first because the collection from that valley is larger than the Punaruu series.

**Partula nodosa composita var. nov.—Taapuna Valley.**

In 1906 the coastward portion of this valley yielded 158 adults of this species out of 182 of all kinds, or 86.8 per cent; in 1909 the interior part was explored, and out of 369 adults of all species, 155 or 42 per cent were *nodosa*. These facts show that *P. nodosa* is more abundant in the lower levels than it is in the interior, as fewer specimens were secured during a longer period of collection on the second occasion. They also indicate that the lower relative frequency in the remote parts of the valley is due to the greater abundance of *P. otaheitana* in the interior, for the absolute numbers of *nodosa* secured in the two years are virtually the same, yet the percentage of the whole population is much smaller in the second year's collection.

In detail, the four distinguishable color-divisions are as follows:

*Class I*, *pallidior* Pilsbry: Plain, light, and unbanded shells with a white, whitish-yellow, or creamy ground-color, more or less streaked transversely with yellowish-brown (figs. 9, 10, and 31, plate 22).

*Class II*, *trilineata* Pease: Upon ground-colors like the above or on brownish-yellow backgrounds revolving bands are developed. The full number of bands is three: one median, one subsutural, and one basal, of which the first is usually more pronounced. These bands vary from narrow and interrupted rows of spots to connected and progressively wider and darker lines of deep reddish-brown. White sutural areas are usually evident (figs. 11 to 21, 31, and 32, plate 22).

*Class III*, *concrescens* Cr.: The subsutural and median bands are connected by similar color so as to form a broad revolving zone which is sharply delimited by the white sutural area and by the uncolored area between the basal band and the "median" component of the broad zone. The bands grade from light yellowish-brown to deep seal-brown or purplish (figs. 22 to 25, plate 22).

*Class IV*, *nodosa* Cr.: The shell is unicolored, chestnut-brown, seal-brown, deep or light purplish-brown, with a white sutural area like that of Classes II and III, although this may be vaguely defined or even lacking (figs. 26 to 30, 34, and 35, plate 22).

The make-up of the 1909 series is as follows:

Class.	Dextral.		Sinistral.		All.	
	No.	Per cent.	No.	Per cent.	No.	Per cent.
I . . . .	6	4.0	1	14.3	7	4.5
II . . . .	65	43.9	3	42.8	68	43.9
III . . .	20	13.5	0	....	20	12.9
IV . . .	57	38.5	3	42.8	60	38.7
Total .	148	....	7	....	155	....

All four divisions are represented in the dextral series of 1906, but unfortunately the colors of most of the shells were altered by contaminated formalin and the relative numbers in the several classes can not be determined with certainty. Only one sinistral specimen was obtained in the lower valley, and this was an immature member of Class II.

TABLE 38.—*Partula nodosa composita*. Taapuna Valley.

MEAN VALUE.								
Group.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.	
		mm.	mm.	p. ct.	mm.	mm.	p. ct.	p. ct.
Class I, 1909, dex.	6	16.0500 ± .1763	9.7333 ± .1074	60.3334 ± .2487	8.6663 ± .1539	6.8000 ± .0940	78.8334 ± 1.1012	53.8333 ± .5430
Class II, 1909, dex.	64	16.0953 ± .0697	9.6937 ± .0415	60.2969 ± .0580	8.7312 ± .0358	6.8562 ± .0308	78.2500 ± .1885	54.4219 ± .1462
Class III, 1909, dex.	20	15.9050 ± .0908	9.7100 ± .0518	60.9000 ± .2356	8.5500 ± .0638	6.8600 ± .0473	80.1500 ± .3279	53.7000 ± .2505
Class IV, 1909, dex.	57	15.7027 ± .0811	9.5281 ± .0413	60.5526 ± .2197	8.4579 ± .0427	6.7070 ± .0376	79.3948 ± .2429	53.5176 ± .1574
All, 1909, dex. . . . .	147	15.9153 ± .0470	9.6333 ± .0259	60.4796 ± .1240	8.5979 ± .0261	6.7966 ± .0208	78.9762 ± .1434	53.9489 ± .0999
All, 1906, dex. . . . .	151	16.0692 ± .0433	9.6867 ± .0179	60.1623 ± .1073	8.6443 ± .0244	6.8059 ± .0185	78.6987 ± .1538	53.6457 ± .0989
All, dex. . . . .	298	15.9933 ± .0320	9.6604 ± .0170	60.3188 ± .0820	8.6215 ± .0179	6.8013 ± .0128	78.8356 ± .1053	53.7953 ± .0705
1909, sin. . . . .	6	15.9000 ± .2673	9.9000 ± .1350	62.3333 ± .5372	8.6333 ± .0936	6.6667 ± .0866	76.8333 ± .9360	54.3333 ± .3693
STANDARD DEVIATION.								
Class I, 1909, dex.	6	0.6403 ± .1246	0.3902 ± .0759	0.9031 ± .1758	0.5588 ± .1088	0.3416 ± .0664	3.3993 ± .7786	1.9720 ± .3839
Class II, 1909, dex.	64	.8267 ± .0493	.4924 ± .0293	.6876 ± .0410	.4247 ± .0253	.3661 ± .0218	2.2360 ± .1333	1.7347 ± .1034
Class III, 1909, dex.	20	.6020 ± .0642	.3434 ± .0366	1.5620 ± .1666	.4232 ± .0451	.3137 ± .0334	2.1743 ± .2318	1.6613 ± .1771
Class IV, 1909, dex.	57	.9081 ± .0573	.4625 ± .0292	2.4596 ± .1553	.4783 ± .0302	.3875 ± .0245	2.7189 ± .1717	1.7621 ± .1113
All, 1909, dex. . . . .	147	.8460 ± .0332	.4668 ± .0183	2.2299 ± .0877	.4697 ± .0185	.3742 ± .0147	2.5775 ± .1014	1.7966 ± .0706
All, 1906, dex. . . . .	151	.7889 ± .0306	.3271 ± .0126	1.9561 ± .0759	.4453 ± .0172	.3366 ± .0131	2.8026 ± .1087	1.8028 ± .0699
All, dex. . . . .	298	.8211 ± .0227	.4353 ± .0120	2.1016 ± .0580	.4580 ± .0126	.3556 ± .0098	2.6975 ± .0744	1.8060 ± .0498
1909, sin. . . . .	6	.9709 ± .1890	.4899 ± .0095	1.9508 ± .3799	.3399 ± .0662	.3144 ± .0612	3.3993 ± .0662	2.7938 ± .2611

The statistical description of the measurable and proportionate characters of the shells is given in table 38. In comparison with other colonies, the figures show a relatively large size; this and the complex make-up of the colony may be taken as the distinctive characters of the var. *composita*, so named for purposes of reference.

The comparison of dextral and sinistral shells must be made on the basis of the 1909 material alone, because adult reversed individuals were taken in that year only. Small as the sinistral group is, the differences between the contrasted groups

are well marked in everything save total length and aperture length. The proportionate figures show decidedly significant peculiarities of the reversed group.

A second analytical result follows from the data given, viz, that the series of 1906 (from the lower level) differs from the 1909 collection (which was taken in the higher parts of the valley). Without enumerating the details, it may be said that the former shells are more elongated and more slender in proportions.

Finally, we may compare the four color-classes of the dextral 1909 series, omitting the 1906 collection for the reasons stated. It appears that Classes I and II are much alike in statistical characters, while Classes III and IV form a couple. At first sight it would seem that the two classes of unbanded shells ought to resemble each other, and that the two classes of banded individuals should be similar in other respects. The facts are otherwise, whatever their significance may be. The pillar tooth is variously developed (table 39), being absent in only a small percentage of the shells. In more than 83 per cent it is prominent, attaining a large size in a few cases.

TABLE 39.—*Partula nodosa composita*. Taapuna Valley.

TOOTH.									
Series.	None.		Trace.		Tooth.		Large tooth.		Total.
	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.	
1909, dextral....	6	....	21	....	118	....	3	....	148
1909, sinistral...	0	....	2	....	5	....	0	....	7
1906, dextral....	5	....	12	....	139	....	2	....	158
Total.....	11	3.5	35	11.1	262	83.7	5	1.6	313
FECUNDITY.									
Series.	Records.	Gravid.	Per cent gravid.	Eggs.	Young.	Total contents.	Average for gravid.	Average for all.	
1909, dextral.....	125	49	39.2	67	13	80	1.6	0.6	
1909, sinistral....	6	2	33.3	0	3	3	1.5	1.5	
1909, all.....	131	51	38.9	67	16	83	1.6	0.6	
1906.....	122	43	35.2	27	44	71	1.6	0.6	
HEREDITY: COLOR-PATTERN.				HEREDITY: COIL.					
	Young, unbanded.	Young, banded	Total.		Young, dextral.	Young, sinistral.	Total.		
Adults, unbanded..	6	1	7	Adults, dextral....	57	0	57		
banded....	7	2	9	sinistral....	0	3	3		
Total.....	13	3	16	Total.....	57	3	60		

The statistics relating to fecundity show a low productivity in both years (table 39). The percentage of gravid individuals is slightly higher for the drier season of 1909, but in both years the figures are low as compared with those for many colonies of *P. clara*. Still more striking are the low percentages of young and eggs, as given in the last two columns; these are substantially the same for the wet season of 1906 and the drier season of 1909.

The statistics of heredity (table 39) are entirely trustworthy in the case of the coil; each form breeds true, as far as the meager figures go. In the matter of color, however, the observations are less significant, owing to the weak development of ground-color and color-pattern until the young snail is nearly ready to leave its parent. In the immature condition it is impossible always to discriminate between the two classes of unbanded, or between the two groups of banded shells. Nevertheless, there are enough positive data to prove that plain parents produce banded young, and *vice versa*; hence the several classes of this variety are not so greatly differentiated as to be physiologically discontinuous.

*Partula nodosa composita* var. nov.—Punaruu Valley.

The topographical features of this valley—the original locality designated by Garrett—have been described and illustrated on earlier pages. Collections were made in 1906, 1908, and 1909, from substantially the same segment of the valley. The snails agree closely with those of Taapuna, to which, indeed, they stand in an ancestral relation; hence by prior right they bear the same varietal name, *composita*.

The first specimens of *nodosa* were taken at about  $1\frac{1}{2}$  miles from the coast, at a height of only 125 feet above the sea-level. From this point inward they increased in numbers, occurring on both sides of the stream, and not from the south side solely, where Garrett obtained them. At a little over 3 miles inland, *nodosa* disappeared and only *P. otaheitana* was taken; the barometric level at the limit of *nodosa*'s range was 350 feet. Since Garrett's time, therefore, this species has come to occupy both sides of the valley floor, for a radial distance in excess of the 0.75 mile specified by Garrett.

TABLE 40.—*Partula nodosa composita*. Punaruu Valley.

Year.	No. of adults.	No. of adolescents.	Class I.			Class II.			Class III.			Class IV.		
			Adults.	Adolescents.	Per cent adults.	Adults.	Adolescents.	Per cent adults.	Adults.	Adolescents.	Per cent adults.	Adults.	Adolescents.	Per cent adults.
1906.....	73	48	17	7	23.3	50	37	68.5	5	3	6.8	1	1	1.3
1908.....	35	6	6	1	17.1	28	5	80.0	1	0	2.8	0	0	0
1909.....	78	50	42	24	53.8	36	25	46.1	0	1	0	0	0	0
All.....	186	104	65	32	34.9	114	67	61.3	6	4	3.2	1	1	0.5

Although *nodosa* inhabits a restricted and uninterrupted region of the valley, the three annual series from this area are by no means the same as regards proportionate numbers in the four color-classes. The specific facts are given in table 40. As compared with the colony of Taapuna, the Punaruu group as a whole includes more individuals of Class I, while Classes III and IV are very poorly represented. It is certainly noteworthy that only one example of the last group should be found when more than one-third of the 1909 shells of Taapuna belong to this class. The shells of Class I are more strongly strigated than in Taapuna (figs. 1 to 4, plate 23). The white sutural area is more prominently displayed in the banded shells of Class II (figs. 5 to 11, plate 23) as well as in those of Classes III and IV (figs. 12 and 13, plate 23), where it is more sharply marked by contrast with the general dark ground-color.



The statistical characters of the Punaruu shells are given in table 41, and from these it appears that the three annual series differ in their measurements just as they do in the representation of the several color-types. The colony is by no means as homogeneous as might be expected from its circumscribed area of habitation. The comparison of the colony as a whole with that of Taapuna may be deferred to the concluding summary.

TABLE 41. *Partula nodosa composita*. Punaruu Valley.

MEAN VALUE.								
Group.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.	
		<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>p. ct.</i>
1906.....	68	15.4823 ± .0353	9.5617 ± .0325	61.6323 ± .1605	8.4264 ± .0356	6.8676 ± .0295	81.5882 ± .1723	54.2794 ± .1261
1908.....	34	15.7823 ± .1173	9.6176 ± .0607	60.9706 ± .2122	8.5059 ± .0670	6.9353 ± .0509	81.3823 ± .2979	53.7353 ± .2156
1909.....	58	15.5672 ± .0687	9.5348 ± .0395	61.3758 ± .1471	8.3689 ± .0365	6.8207 ± .0337	81.4310 ± .2716	53.6207 ± .1517
Class I.	51	15.6029 ± .0786	9.6411 ± .0361	61.7745 ± .1885	8.4804 ± .0396	6.9117 ± .0320	81.3039 ± .2578	54.2058 ± .1488
Class II.	102	15.6382 ± .0603	9.5451 ± .0329	61.1863 ± .1179	8.4117 ± .0439	6.8627 ± .0273	81.5784 ± .1706	53.8333 ± .1146
Class III.	6	15.2000 ± .2224	9.3000 ± .0899	61.3333 ± .2938	8.1666 ± .0936	6.6000 ± .0693	81.3333 ± .6441	53.5000 ± .4900
Class IV.	1	15.5000 ....	9.1000 ....	58.5000 ....	8.0800 ....	6.3000 ....	78.5000 ....	51.5000 ....
All.....	160	15.5769 ± .0468	9.5637 ± .0245	61.3625 ± .0986	8.4212 ± .0248	6.8650 ± .0207	81.4875 ± .1382	53.9250 ± .0899
STANDARD DEVIATION.								
1906.....	68	0.4323 ± .0249	0.3975 ± .0230	1.9622 ± .1135	0.4351 ± .0252	0.3608 ± .0208	2.1065 ± .1218	1.5420 ± .0891
1908.....	34	1.0139 ± .0829	.5251 ± .0429	1.8349 ± .1500	.5790 ± .0474	.4405 ± .0360	2.5755 ± .2106	1.8639 ± .1524
1909.....	58	.7755 ± .0486	.4457 ± .0279	1.6613 ± .1040	.4120 ± .0258	.3804 ± .0238	3.0674 ± .1920	1.7128 ± .1073
Class I.	51	.8325 ± .0556	.3825 ± .0255	1.9959 ± .1333	.4196 ± .0280	.3394 ± .0226	2.7298 ± .1823	1.5755 ± .1052
Class II.	102	.9033 ± .0426	.4933 ± .0232	1.7656 ± .0834	.6577 ± .0310	.4085 ± .0193	2.5541 ± .1206	1.7169 ± .0810
Class III.	6	.8077 ± .1572	.3265 ± .0636	1.0671 ± .2077	.3399 ± .0662	.2516 ± .0490	2.3391 ± .4554	1.7795 ± .3465
Class IV.	1	.....	.....	.....	.....	.....	.....	.....
All.....	160	.8783 ± .0331	.4596 ± .0173	1.8488 ± .0697	.4654 ± .0175	.3883 ± .0146	2.5908 ± .0977	1.6865 ± .0636

The four color-classes differ somewhat, although only Classes I and II comprise enough individuals to warrant a statistical comparison. In two of the three proportionate determinations, the differences in question appear to be significantly large in relation to their probable errors.

The tooth is almost invariably developed to some degree (table 42). Only two shells are devoid of any trace of this structure.

The statistics of fecundity (table 42) show a low rate of reproductive activity in the case of the 1906 series, taken in the wet and hot season; the low rate is indicated both in the percentage of gravid individuals and in the number of young and eggs borne by the reproducing snails. In 1908 remarkably high percentages were obtained, but in the corresponding period of 1909 the figures are low again. It would seem that the resumption of breeding is not entirely determined by the advent of heavier rains and hotter weather.

The data of heredity (table 42) prove only that banded young are sometimes produced by plain parents, and that plain young appear among the offspring of contrasted adults. As in Taapuna the color-classes are not absolutely fixed and

separate, although they may be tending toward the conditions of true subspecies or varieties.

TABLE 42.—*Partula nodosa composita*. *Punaruu Valley*.

TOOTH.					
	0	Trace.	Tooth.	Large tooth.	Total.
1906 .....	1	11	59	1	72
1908 .....	0	0	35	0	35
1909 .....	1	4	72	1	78
Total .....	2 (1 per cent)	15 (8.1 per cent)	166 (89.7 per cent)	2 (1 per cent)	185

FECUNDITY.								
Group.	Records.	Gravid.	Per cent gravid.	Eggs.	Young.	Total contents.	Average for gravid	Average for all.
1906 .....	59	17	2.9	8	18	26	1.5	0.4
1908 .....	32	29	90.6	63	44	107	3.7	3.3
1909 .....	77	18	2.3	42	5	47	2.6	0.6
All .....	168	64	38.1	113	67	180	2.8	1.1

HEREDITY.			
	Young, plain.	Young, bands.	Total.
Adults: Plain....	14	2	16
Banded..	14	37	51
Total.....	28	39	67

***Partula nodosa læva* Pilsbry.—Maruapoo Valley.**

The collections from this small gorge are of exceptional interest: (1) because the locality is so close to the area described by Garrett as the original home of the species; (2) because of Mayer's observations in 1899, which afford a basis of comparison with later studies, and (3) on account of the intrinsic peculiarities of the Maruapoo colony. Most of the shells are sinistral, and hence the variety of this region is well named *læva*, although dextral examples must be included under that term. A similar inconsistency is obligatory in the case of dextral individuals belonging to var. *sinistrorsa* of *P. otaheitana*, to be described later.

Not only is the coil predominantly reversed in this colony, but the colors are not identical in most cases with those of var. *composita*. The shells present a bewildering series of variations in this respect, wherefore it is not profitable to attempt to classify them, save into the two classes of "plain" and "banded." The first class (figs. 14 to 16 and 20 to 28, plate 23) includes individuals like those of Classes I and IV of *composita*, but all gradations between light and dark extremes also occur in sufficient numbers to render the establishment of discontinuous groups impossible; the intermediates may exhibit a uniform ground-color, or they may have a dark uniform spire above a peculiarly striated basal whorl. The banded shells (figs. 17

to 19 and 29 to 36, plate 23, and figs. 1 to 6, plate 24) are sometimes identical in coloration with Class II examples of var. *composita*, but as a rule the ground-color is a darker yellowish-brown or brown, the subsutural and even the basal band may be absent, and the sutural white zone is rarely developed. Light or dark reddish examples occur sporadically. Variations in size and shape are also evident, as the several illustrations demonstrate.

The series of 1907 was obtained from the vegetation along the rough and rocky borders of the stream, in the lower valley. The first snails were found on *Colocasia*, a mile from the shore and about a quarter of a mile from the mouth of the valley, where the barometer registered a level of 400 feet; all were sinistral, and examples of *P. clara* or *P. hyalina* were associated with them. In 1908 more extensive collections were taken in the forests above the steep cliffs that abruptly divide the valley into lower coastward and higher inland parts. Snails were found from 250 feet to 900 feet altitude, the limit of exploration. Heavy rains had fallen for four consecutive days, and in consequence the animals were actively crawling about on all kinds of vegetation and even on the bare volcanic earth itself. This year specimens of *P. otaheitana*, *P. clara*, and *P. hyalina* were obtained, as well as dextral individuals of *nodosa*.

The proportionate numbers of plain and banded individuals differ in the two annual series, neither of which agrees exactly with Mayer's collection (table 43). In the lowland collection all are sinistral and the banded class predominates, while in both the sinistral and dextral divisions of 1908 the plain color-type is more abundantly represented.

TABLE 43.—*Partula nodosa læva*. Maruapoo Valley. Classification of material.

Group.	1907 (personal).		1908 (personal).		1899 (Mayer).	
	No.	Per cent.	No.	Per cent.	No.	Per cent.
Sinistral, plain.....	20	38.4	545	73.3	139	39
Sinistral, banded.....	32	61.5	170	22.9	55	55
Dextral, plain.....	..	....	17	2.3	<sup>1</sup> 4	4
Dextral, banded.....	..	....	11	1.5	2	2
Total.....	52	....	743	....	100	..

<sup>1</sup>Including faintly banded individuals.

The statistics relating to the Marupoo shells are given in table 44. The series of 1907 comprises individuals that are larger than the reversed group of 1909, and the differences are significant in all four of the direct measures; the former are somewhat stouter in shell proportions, while in aperture proportions and in the relative length of the aperture they show more decided divergence.

The dextral snails of 1908 form a group with essentially distinct characters, but they do not tend to resemble the dextral colony of Punaruu, as they should if they were stragglers from that neighboring valley. They are undoubtedly relatives of their reversed associates, even though they differ from the latter in statistically definite degrees.

TABLE 44.—*Partula nodosa læva*. Maruapoo Valley.

MEAN VALUE.								
Group.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.	
		<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>p. ct.</i>
Sin., plain, 1907....	20	15.5900±.1292	9.4200±.0534	60.4000±.3266	8.4200±.0591	6.7900±.0560	80.5000±.4130	53.9000±.2356
Sin., banded, 1907..	31	15.8145±.0879	9.5129±.0424	60.2420±.2363	8.4939±.0474	6.8032±.0379	80.2097±.3443	53.4678±.1909
Sin., plain, 1908....	430	15.5418±.0234	9.3256±.0132	59.9991±.0788	8.0991±.0127	6.3703±.0111	79.3372±.0959	51.8814±.0569
Sin., banded, 1908..	168	15.5160±.0400	9.3381±.0213	60.1310±.1296	8.2000±.0200	6.3250±.0216	79.2678±.1740	52.7262±.0901
Dex., plain, 1908....	17	15.7911±.1327	9.2530±.0749	58.4412±.3148	8.2412±.0799	6.3824±.0550	77.5000±.4627	52.2295±.2441
Dex., banded, 1908..	11	15.3227±.1811	9.1728±.0922	59.6819±.5117	8.1363±.0881	6.3728±.0800	78.4091±.6457	53.0455±.3641
Sin., all, 1907.....	51	15.7264±.0744	9.4804±.0333	60.3039±.1926	8.4647±.0372	6.7980±.0317	80.3235±.2650	53.6372±.1496
Sin., all, 1908.....	598	15.5346±.0202	9.3291±.0112	60.0218±.0671	8.1274±.0108	6.3576±.0100	79.3178±.0853	52.1221±.0495
Dex., all, 1908.....	28	15.6071±.1113	9.2215±.0583	58.9286±.2879	8.2000±.0599	6.3786±.0459	77.8572±.3560	52.4286±.2070
Sin., all.....	649	15.5497±.0196	9.3409±.0107	60.0439±.0642	8.1539±.0107	6.3922±.0100	79.3968±.0812	52.2412±.0484
STANDARD DEVIATION.								
Sin., plain, 1907....	20	0.8569±.0913	0.3544±.0377	2.1656±.2309	0.3919±.0418	0.3713±.0396	2.7386±.2920	1.5620±.1666
Sin., banded, 1907..	31	.7261±.0621	.3499±.0300	1.9505±.1671	.3915±.0335	.3126±.0268	2.8420±.2434	1.5757±.1350
Sin., plain, 1908....	430	.7204±.0165	.4069±.0093	2.4358±.0557	.3913±.0090	.3402±.0078	2.9651±.0678	1.7583±.0402
Sin., banded, 1908..	168	.7696±.0283	.4105±.0150	2.4917±.0916	.3854±.0141	.4153±.0153	3.3433±.1230	1.7310±.0637
Dex., plain, 1908....	17	.8111±.0938	.4577±.0529	1.9242±.2226	.4887±.0565	.3363±.0389	2.8284±.3272	1.4923±.1726
Dex., banded, 1908..	11	.8904±.1280	.4534±.0652	2.5161±.3618	.4333±.0623	.3933±.0565	3.1753±.4566	1.7907±.2574
Sin., all, 1907.....	51	.7878±.0526	.3526±.0235	2.0390±.1362	.3935±.0263	.3355±.0224	2.8055±.1874	1.5845±.1058
Sin., all, 1908.....	598	.7346±.0143	.4081±.0079	2.4321±.0474	.3923±.0076	.3634±.0070	3.0925±.0603	1.7940±.0350
Dex., all, 1908.....	28	.8736±.0787	.4578±.0412	2.2588±.2035	.4705±.0424	.3599±.0324	2.7930±.2517	1.6241±.1464
Sin., all.....	649	.7407±.0139	.4061±.0076	2.4239±.0454	.4027±.0076	.3783±.0071	3.0678±.0565	1.8246±.0342

Comparing the plain and banded groups with one another, it appears that the relations of one annual series are reversed in the other. The unbanded shells are collectively smaller than the others in the 1907 lot, but in the richer collection from the higher level they are larger, in both the sinistral and dextral groups.

The pillar-tooth has been treated statistically in this colony and the figures are given in table 45. The shells devoid of a tooth constitute a class with index 1; those with a "trace" make up the group with index 2, and so forth. The data disclose well-marked differences between the plain and banded shells of the dextral section, but otherwise the comparable series seem to be essentially alike in this character.

The statistics of fecundity (table 46) refer to the 1908 series, and low degrees of productivity are indicated exactly as in the case of the 1909 series from Punaruu. All of the specimens obtained in the valley during 1907 were brought back alive for laboratory study, and hence their records are not available.

Owing to the remarkably low productivity of the large 1908 collection, few data are at hand for the determination of the genetic relationships between the two

color-classes and of the two form-classes (table 46). All of the plain adults produced only plain young, while the banded adults bore both kinds; certainly these classes can not be regarded as distinct. Mayer's results on this point are confirmed. The two form classes, sinistral and dextral, bred true in my material; but in Mayer's material a dextral individual bore one sinistral offspring and 4 out of 51 young produced by sinistral parents were dextral.

TABLE 45.—*Partula nodosa læva*. Maruapoo Valley. Pillar tooth.

Group.	Tooth.					Total number.	Mean value. Index.	Standard deviation.
	0	Trace.	Tooth.	Large tooth.	Very large tooth.			
Sinistral, plain, 1907.....	2	1	14	3	0	20	2.9000±.1158	0.7681±.0819
Sinistral, banded, 1907.....	1	4	22	4	1	32	3.0000±.0856	.7184±.0605
Sinistral, plain, 1908.....	19	71	298	36	10	434	2.8779±.0228	.7063±.0161
Sinistral, banded, 1908.....	9	34	97	23	7	170	2.9118±.0434	.8391±.0307
Dextral, plain, 1908.....	0	1	12	3	1	17	3.2353±.1054	.6444±.0745
Dextral, banded, 1908.....	1	3	5	2	0	11	2.7273±.1754	.8624±.1240
Sinistral, all, 1907.....	3	5	36	7	1	52	2.9616±.0685	.7328±.0484
Sinistral, all, 1908.....	28	105	395	59	17	604	2.8875±.0205	.7462±.0145
Dextral, all, 1908.....	1	4	17	5	1	28	3.0571±.0990	.7771±.0700
Sinistral, all.....	31	110	431	66	18	656	2.8933±.0196	.7454±.0138

TABLE 46.—*Partula nodosa læva*. Maruapoo Valley.

FECUNDITY.								
Group.	Records.	Gravid.	Per cent gravid.	Eggs.	Young.	Total contents.	Average for gravid.	Average for all.
Sinistral, 1908.....	561	219	39.0	269	68	337	1.5	0.6
Dextral, 1908.....	27	11	40.7	14	1	15	1.4	0.5
All.....	588	230	39.1	283	69	352	1.5	0.6
HEREDITY (1908).								
	Young.			Total.				
	Sinistral, plain.	Sinistral, banded.	Dextral, banded.					
Adults, sinistral, plain.....	50	0	..	50				
Adults, sinistral, banded.....	6	12	..	18				
Adults, dextral, banded.....	..	..	1	1				
Total.....	56	12	1	69				

While it is theoretically possible that the directly coiled snails may be the descendants of *recent* emigrants from Punaruu, this does not seem probable. Obviously these individuals are genetically related to the sinistral group, as proven by the statistics of heredity and of form. Furthermore, the peculiar color-characters of the latter are shared with the former, in most cases. The absence of the white

sutural band, the darker general ground-color, and the indistinctness of the band are characters which ally the two groups and separate them from all other colonies whose members are exclusively or predominantly dextral. The variety *læva* is undoubtedly a product of some original stock of *nodosa*, but its dextral components seem to be secondarily derived from peculiarly colored and reversed antecedents.

***Partula nodosa exigua* var. nov.—Atehi Valley.**

Atehi or Hapaa Valley is a small gorge running parallel with Maruapoo about 0.75 mile to the south. Its mouth is separated by wooded ridges from the openings of Maruapoo and Papehuc. On entering the valley, the floor rises rapidly, being 450 feet in barometric level at 0.75 mile. The stream runs in a steep-walled gorge, as in the lower part of Maruapoo. On account of the ruggedness of the region, efforts to collect the snails from Atehi and Maruapoo were more arduous than anywhere else in Tahiti.

Out of 450 adult snails of all species only 4 specimens of *nodosa* were secured in the course of two journeys into Atehi Valley. This small number is remarkable in view of the proximity of Maruapoo and Papehuc, in both of which *nodosa* figures largely. Yet even more astonishing is the wide divergence of these 4 specimens from the shells described earlier; were it not for somewhat similar individuals of the Papehuc colony, the Atehi examples would be justly denominated a separate species!

TABLE 47.—*Partula nodosa exigua*. Atehi Valley.

STATISTICAL CHARACTERS.			TOOTH.		FECUNDITY.	
Character.	Mean value.	Standard deviation.				
Shell, length, mm.....	14.0750 ± .2225	0.4918 ± .1573	Trace.....	0	Records.....	4
width, mm.....	8.8500 ± .0559	.1658 ± .0395	Tooth.....	3	Gravid.....	4
proportion, per cent...	62.7500 ± .6021	1.7853 ± .4258	Large tooth.....	1	Eggs.....	4
			Very large tooth...	0		6
Aperture, length, mm.....	7.7500 ± .0876	.2598 ± .0619	Total.....	4	Total contents.....	10
width, mm.....	5.8500 ± .0559	.1658 ± .0395			Average for gravid and for all.....	2.5
proportion, per cent.....	76.0000 ± 1.1316	3.3556 ± .8002				
Length aperture ÷ length shell, proportion.....	54.5000 ± .5841	1.7320 ± .4130				

<sup>1</sup>All plain and dextral.

The 4 shells (figs. 7 to 10, plate 24) are very small, dextral, and unbanded; their reduced size warrants the use of the term *exigua* as a varietal distinction. In ground-color they are uniform brown, from dark to chocolate, and the apices of all have a purplish tinge. The nodosity on the columellar border of the aperture is evanescent in 2 specimens and absent in the other 2. In surface sculpturing and in the character of the whorls they agree with dextral examples of true *nodosa* existing in valleys to the south; they differ absolutely from the solid brown type of *P. otaheitana* with a sinistral coil which inhabits Atehi. The other dextral specimens from this valley belong to *P. hyalina* and *P. clara*, with which the four examples under consideration can not possibly be confused.

The statistical characters (table 47) show how greatly this small series differs from previously described colonies. The tooth is present in every shell (table 47). All four were gravid (table 47), and together they bore 6 plain brown and dextral young, besides 4 eggs; the absence of sinistral young is negative, but competent evidence that these snails are not dextral and otherwise modified sports produced by the plain sinistral *P. otaheitana* of this valley.

***Partula nodosa intermedia* var. nov.—Papehue Valley.**

In the three remaining valleys of the range of *nodosa* the shells resemble var. *composita* of the north, but in some respects depart in the direction of the Atehi association. The varietal name *intermedia* is therefore chosen for these southern colonies, of which the one existing in Aoua Valley is the most characteristic.

Papehue Valley (plate 15*b*) lies about 0.75 mile to the south of Atehi, to which it is parallel. It is much larger than the latter, but its broken and rugged topographical features are similar. The first snails were found at a distance of 1 mile from the coast, and from this point inward to a limit of 3 miles. In 1906 this entire area was investigated, and in 1907 the outer part was revisited; the area of collection in the first year thus included that of the second, together with the remoter and higher part of the valley. All of the snails secured were dextral.

Two classes only can be distinguished here, namely, "plain" and "banded" shells. The latter (figs. 19 to 24, plate 24) conform to the typical Class II shells of Taapuna and Punaruu (var. *composita*, color-form *trilineata*) and they differ from the majority of the

	1906		1907	
	Adults.	Per cent.	Adults.	Per cent.
Plain . . . .	54	47.3	54	56.2
Banded . .	60	52.6	42	43.7

banded individuals of the intervening colony in Maruapoo Valley. No exact counterparts of Class III (var. *composita*, color-form *confluens*) occur, but some (fig. 23) display considerable suffusion between the subsutural and median stripes, and are thus transitional to Class III. The "plain" shells (figs. 11 to 18, plate 24) are evenly colored as a rule. A few exhibit ill-defined strigations which never attain the distinctness of similar markings in Class I shells of var. *composita* from Punaruu. In color they range from light brown through intermediate shades to dark brown and solid purplish-brown, with the white sutural area more or less sharply defined in the majority. Some of these last resemble many of the plain shells from Maruapoo, but the direction of their coil is exactly opposite.

Certain members of both classes have the nodosity on the columella border greatly reduced (figs. 11 and 19, plate 24). They are the smaller in size, and the plain ones among them resemble the Atehi shells so closely as to dispel all doubts as to the morphological relationship between the peculiar Atehi specimens and the Aoua association. The relative numbers in the two distinguishable classes differ in the two annual series.

The journey of 1906 extended into the deeper parts of the valley and covered the ground of 1907, together with the higher regions. It follows that the first series includes representatives of the second year's area of collection, as well as snails

TABLE 48.—*Partula nodosa intermedia*. Papehue Valley.

MEAN VALUE.								
Group.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.	
		<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>p. ct.</i>
Plain, 1906 . . .	53	14.8349 ± .0668	9.1642 ± .0382	61.6886 ± .1371	8.0547 ± .0346	6.3680 ± .0274	79.1038 ± .2124	54.0660 ± .1411
Banded, 1906 . .	59	14.8263 ± .0626	9.3305 ± .0329	62.9068 ± .1679	8.1915 ± .0334	6.5407 ± .0230	79.9068 ± .2379	55.1780 ± .1169
Plain, 1907 . . .	52	14.6519 ± .0372	9.1154 ± .0404	62.2692 ± .2039	8.0039 ± .0319	6.3346 ± .0313	79.1346 ± .2092	54.4038 ± .1274
Banded, 1907 . .	41	14.7281 ± .0606	9.1878 ± .0326	62.4024 ± .1985	8.0074 ± .0354	6.4269 ± .0278	80.2805 ± .2332	54.3049 ± .1632
All, 1906 . . . . .	112	14.8304 ± .0458	9.2500 ± .0256	62.3303 ± .1164	8.1268 ± .0245	6.4589 ± .0186	79.5268 ± .1628	54.6518 ± .0975
All, 1907 . . . . .	93	14.6855 ± .0281	9.1473 ± .0269	62.3279 ± .1438	8.0054 ± .0237	6.3753 ± .0216	79.6398 ± .1607	54.3602 ± .1013
All . . . . .	205	14.7647 ± .0311	9.2044 ± .0187	62.3292 ± .0911	8.0717 ± .0173	6.4210 ± .0142	79.5780 ± .1150	54.5192 ± .0707
STANDARD DEVIATION.								
Plain, 1906 . . .	53	0.7209 ± .0472	0.4126 ± .0270	1.4802 ± .0969	0.3739 ± .0245	0.2957 ± .0194	2.2931 ± .1502	1.5235 ± .0998
Banded, 1906 . .	59	.7136 ± .0442	.3752 ± .0232	1.9144 ± .1187	.3815 ± .0236	.2624 ± .0162	2.7129 ± .1682	1.3332 ± .0826
Plain, 1907 . . .	52	.5634 ± .0372	.4318 ± .0285	2.1802 ± .1442	.3408 ± .0225	.3344 ± .0221	2.2363 ± .1479	1.3624 ± .0901
Banded, 1907 . .	41	.5753 ± .0428	.3093 ± .0230	1.8846 ± .1403	.3367 ± .0250	.2641 ± .0196	2.2142 ± .1649	1.5495 ± .1154
All, 1906 . . . . .	112	.7193 ± .0324	.4018 ± .0181	1.8266 ± .0823	.3840 ± .0173	.2917 ± .0131	2.5546 ± .1151	1.5306 ± .0689
All, 1907 . . . . .	93	.5700 ± .0281	.3851 ± .0190	2.0563 ± .0992	.3390 ± .0167	.3088 ± .0153	2.2981 ± .1136	1.4487 ± .0716
All . . . . .	205	.6598 ± .0220	.3978 ± .0132	1.9343 ± .0644	.3693 ± .0122	.3024 ± .0100	2.4422 ± .0813	1.5004 ± .0500

TABLE 49.—*Partula nodosa intermedia*. Papehue Valley.

TOOTH.								
Series.	0	Trace.	Tooth.	Large tooth.	Total.			
1906.....	2	10	101	1	114			
1907.....	4	6	84	2	96			
All.....	6	16	185	3	210			
FECUNDITY.								
Series.	Records.	Gravid.	Per cent gravid.	Eggs.	Young.	Total contents.	Average for gravid.	Average for all.
1906...	24	6	25.0	6	2	8	1.3	0.3
1907...	63	29	46.0	25	25	50	1.7	0.8
All.....	87	35	40.2	31	27	58	1.6	0.7

HEREDITY.			
	Young, plain.	Young, banded.	Total.
Adults: Plain . .	11	5	16
Banded	1	10	11
Total . . . . .	12	15	27



from another part of the colony's range. From the figures, therefore, it is plain that the banded examples greatly outnumber the plain shells in the remoter areas, for in the proximate region they are in the minority, as shown by the data for 1907. This is the reverse of the relation between the two classes as they exist in Maruapoo.

Contrasting the two series on the basis of the statistical determinations (table 48) it appears that the animals of the lower part of the colony are somewhat smaller in absolute measures, while they are narrower in the proportions of the whole shell and of its aperture; in the proportion of aperture length to shell length, its constituents exhibit a higher value. Furthermore, the two classes differ markedly in certain characters, in each of the annual series. Nearly all of the shells bear a pillar tooth (table 49), only 6 out of 210 lacking this feature. In fecundity (table 49) low reproductive rates are indicated for both years.

Heredity of the class character of color is sensibly strict (table 49), especially in the case of banded forms, although allowance must be made for the late appearance of the bands in embryonic development. Scant as the data may be, they prove positively that the two classes are not genetically distinct here, any more than in other valleys.

*Partula nodosa intermedia* var. nov.—Aoua Valley.

This gorge is slightly larger than Papehue, and is the last of the lesser elements in the southward range of *nodosa*. More than 500 specimens of this species were secured here, of which 396 were adult and 115 were partly grown. All were dextral *with the exception of a single immature banded example*. As a whole, the colony stands near the original stock, which is now represented by the Taapuna and Punaruu shells, as all four color-classes of the northern section are clearly distinguishable. Although the intrinsic characters are under consideration here, it is well to point out that the Aoua colony seems to be the direct derivative of var. *composita*, and that it has secondarily given off the colonies of Orofere to the south and Papehue to the north; from the latter, which still resembles the Aoua group on the whole, the Atehi variety, *exigua*, seems to have been produced at a still later period. In brief, the Aoua colony is the typical *intermedia*.

The numbers assignable to the several color-classes are as follows:

Class.	Figures and plates.	Number of adults.	Per cent.
I	Figs. 25, 26, plate 24	2	0.5
II	Figs. 27 to 30, plate 24	321	81.0
III	Fig. 31, plate 24	23	5.8
IV	Figs. 32 to 34, plate 24	50	12.6
		396	99.9

Very light shells like pallidior of var. *composita* reappear, although in small numbers. Class III (*concrescens*) is well represented. The shells of Class IV show a weakly marked white sutural zone, if it appears at all.

The statistical determinations (tables 50 and 51) show that the contrasted classes are not identical in the measurable and proportionate characters of the shells or in the degree to which the pillar tooth is developed. Fecundity (table 51) is low as in the other colonies of this species. Again the parents of any class (omitting the two specimens of Class I) produce their own kind (table 51), but they also bear different kinds of offspring as well.

TABLE 50.—*Partula nodosa*. Aoua Valley.

MEAN VALUE.								
Group.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.	
		<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>p. ct.</i>
Class I.....	2	14.7500±.1431	9.1000±.0	61.5000±.4769	8.0000±.0477	6.5000±.0954	80.5000±.4769	54.5000±.0
Class II.....	309	14.4034±.0263	8.9078±.0157	61.7427±.0820	7.8817±.0144	6.3376±.0121	80.2703±.0961	54.5500±.0596
Class III.....	23	14.3326±.0675	8.9696±.0350	62.5869±.1985	7.9697±.0394	6.3870±.0267	80.1956±.3309	55.4130±.1459
Class IV.....	48	14.5938±.0607	9.2000±.0355	62.9375±.1831	8.0250±.0414	6.4209±.0327	79.8541±.2632	54.9166±.1753
All.....	382	14.4249±.0231	8.9492±.0141	61.9424±.0750	7.9058±.0131	6.3519±.0108	80.2146±.0872	54.6544±.0545
STANDARD DEVIATION.								
Class I.....	2	0.3000±.1012	0	1.0000±.3372	0.1000±.0337	0.2000±.0674	1.0000±.3372	0
Class II.....	309	.6862±.0186	0.4105±.0111	2.1367±.0580	.3749±.0102	.3147±.0085	2.5061±.0679	1.5548±.0421
Class III.....	23	.4904±.0477	.2544±.0247	1.4421±.1403	.2866±.0278	.1938±.0189	2.4035±.2340	1.0597±.1032
Class IV.....	48	.6237±.0429	.3651±.0251	1.8809±.1295	.4255±.0293	.3360±.0231	2.7041±.1861	1.8009±.1239
All.....	382	.6707±.0163	.4079±.0100	2.1708±.0530	.3795±.0093	.3126±.0076	2.5242±.0617	1.5769±.0385

TABLE 51.—*Partula nodosa*. Aoua Valley.

TOOTH.						FECUNDITY (390 RECORDS).		HEREDITY.			
Group.	0	Trace.	Tooth.	Large tooth.	Total.				Young, plain.	Young, banded.	Total.
Class I.	0	0	2	0	2	Gravid.....	103	Adults: Plain (Class IV) .. Banded (Classes II and III)....	12	5	17
Class II.	3	4	314	0	321	Per cent gravid....	34.1				
Class III.	2	1	20	0	23	Eggs.....	137	Total.....	3	23	26
Class IV.	0	2	48	0	50	Young.....	43				
All.....	5	7	384	0	396	Total contents.....	180		15	28	43
						Average for gravid..	1.7				
						Average for all.....	0.5				

***Partula nodosa intermedia* var. nov.—Orofere Valley.**

In discussing the range of *P. nodosa* at an earlier point (p. 90) it was stated that no specimens of this species were obtained in 1907, but that a few were taken in 1908 in Orofere Valley. In the former year the area of exploration extended to a point 3 miles from the coast and included both borders of the stream; in the latter year *nodosa* was discovered on the northern border of the river (on the side adjacent to Aoua Valley), 2 miles from the shore. Ten banded animals were secured on one occasion and 7 banded specimens together with 1 plain shell on a second trip. There

is no doubt that the area from which the snails were secured in 1908 was actually visited in the prior year, and while Orofere *may* have been invaded by immigrants from Aoua as early as 1907, it is significant that no individuals of the species were present in a collection comprising 185 snails of all ages, when one year later 18 out of 92 adults and 10 out of 22 adolescents were *nodosa*. As Garrett describes correctly the variety of *P. otaheitana* existing here, specifying the valley by an old name, and as he states expressly that *nodosa* was found by him *only* in Punaruu, we are justified in concluding that the Orofere colony of *nodosa* has been founded only in the most recent years.

Seventeen of the adult shells are assignable to Class II (fig. 36, plate 24), while the single plain specimen is a small example of Class I (fig. 35, plate 24). All possess a pillar tooth of average size. Only three were gravid, and each one bore a single egg; hence there are no data on heredity. The statistics (table 52) are not especially noteworthy in themselves, but are valuable for the inter-valley comparisons.

TABLE 52.—*Partula nodosa intermedia*. Orofere Valley.

MEAN VALUE.								
Group.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.	
Banded . . . . .	17	<i>mm.</i> 15.4911 ± .1814	<i>mm.</i> 9.3588 ± .0957	<i>p. ct.</i> 60.3824 ± .2963	<i>mm.</i> 8.3353 ± .0967	<i>mm.</i> 6.6764 ± .0800	<i>p. ct.</i> 80.0294 ± .3554	<i>p. ct.</i> 53.7353 ± .2663
Plain . . . . .	1	13.2500 . . . .	8.1000 . . . .	60.5000 . . . .	7.3000 . . . .	5.5000 . . . .	76.5000 . . . .	54.5000 . . . .
All . . . . .	18	15.3667 ± .1899	9.2889 ± .1014	60.3889 ± .2798	8.2778 ± .0988	6.6111 ± .1018	79.8333 ± .3594	53.7778 ± .2531
STANDARD DEVIATION.								
Banded . . . . .	17	1.1088 ± .1283	0.5851 ± .1677	1.8111 ± .2095	0.5910 ± .0684	0.4893 ± .0566	2.1725 ± .2513	1.6280 ± .1883
All . . . . .	18	1.1945 ± .1343	.6376 ± .0717	1.7603 ± .1978	.6214 ± .0699	.6402 ± .0720	2.2608 ± .2541	1.5918 ± .1790

## SUMMARY AND CONCLUSIONS.

Having dealt in severalty with the colonies of *P. nodosa*, it now remains to consider the species as a whole and to formulate the conclusions which may be drawn from the summarized details. Always with due regard to the distinction between the facts themselves and the interpretations of the observations, four general topics are to be discussed, namely, the range of the species as a whole, the variation of the species within its range, the genetic history of the distinguishable varieties, and the factorial value of internal and external causes of differentiation.

I. *Partula nodosa* now inhabits seven valleys in the western quadrant of Tahiti nui, having extended its range to some degree in recent years. The grounds for this statement have been discussed at some length in earlier pages, but additional aspects of the evidence demand further consideration. The fundamental datum is that the species occupies a compact sector comprising 7 valleys in a definite part of Tahiti; hence, in the series of Tahitian species arranged according to the extent of the territory inhabited, *Partula nodosa* stands between the extreme species,

*P. filosa*, existing in a single valley only, and *P. clara* on the other hand, a somewhat differentiated species now found in 52 valleys. Regarding the present geographical limits of *P. nodosa*'s range as derived, and not as unchanged for an indefinite period of time, we may ask whether the prior area of occupation was greater than now, or less than it is at present; that is, whether expansion or contraction has been brought about recently.

In favor of the view that *nodosa*'s range has recently been expanded, we may cite certain intrinsic aspects of the facts as observed and also the collateral evidence provided by other species. Under the first head the most positive detail is the discovery of *nodosa* in limited numbers in Orofere Valley in 1907, when search in the same place was futile only a year earlier. It is not contended that absolutely no individuals of this species inhabited Orofere in 1907, but it is held that the failure to find it in that year and the observation that it formed nearly 7 per cent of the representatives of the valley population in 1908 mean its recent introduction into this habitable area. As for the rest, the facts are not significant. It is unfortunate that Garrett did not state specifically whether he explored Taapuna, and the smaller ravines between Punaruu and Orofere, for in that case a precise comparison could be made with the present state of affairs; we can not determine by the most direct method whether Taapuna, Papehue, and Aoua, etc., have been populated like Orofere since Garrett's time. Indirectly, however, the results of analyzing in detail the several colonies of *nodosa*, as discussed below, materially support the view herein adopted, which for the present must rest upon the single definite fact adduced.

As collateral evidence we may add the positive demonstration already given that *P. clara* has enlarged its territory to a great degree in the past decades, after a period of severe contraction (p. 74 *et seq.*). Furthermore, it will be shown in a subsequent section that certain varieties of *P. otaheitana* have also migrated recently to valleys which they did not inhabit previously.

We may therefore adopt as most probable the view that *P. nodosa* has spread recently from a much smaller area, where it developed its peculiar and distinctive specific characters.

The location of the original area is indicated by the facts to have been toward the northern end of the present range, and that it is probably to be identified with Punaruu Valley. Had it been in the southern part of the present range, where var. *intermedia* now lives, we would expect to find colonies of *nodosa* south of Orofere, if the ability to migrate northward as far as Taapuna were exercised in journeying southward. If, however, Punaruu be assumed to be the original center of dispersal, then the present range is just what would be expected, taking the topographical features into account. Migrants could soon reach Taapuna, over the hills, but the drier and loftier ridges between that valley and Faaa and Tipaerui would be barriers that could be traversed only with great difficulty, if at all; it would seem that they have not yet been crossed, although the Taapuna colony is a flourishing one, both in numbers and vigor. On the same assumption, the greater spread to the southward of Punaruu is natural, for the ridges are not so abrupt and dry and there would be less hindrance offered to the tide of migration setting toward Orofere. In short,

the original smaller area of occupation seems to have been a portion of Punaruu Valley.

But we could not justify the hypothesis that *P. nodosa* arose *de novo*, so to speak, either in Punaruu or in any other valley; this species must have had antecedents from which it has come to differ more or less radically. No other species of its islands displays characters which might be deemed *ancestral* to those of *nodosa*. *P. hyalina* and *P. clara* have attenuated and elongated shells, together with other distinct differentia; *P. otaheitana* varies greatly in Tahiti, but its members, even in valleys situated in or adjacent to the territory of *nodosa*, are readily distinguishable. Only *P. filosa* resembles *nodosa* in form to an appreciable degree, a fact which is undoubtedly significant; but it is sharply restricted to a single valley in the dry and distant northern sector of Tahiti nui, from which migrants could not make their way to the western valleys, there to develop the distinctive qualities of *nodosa* as such. But outside of Tahiti occurs one species that does resemble *nodosa* in coloration as well as form, namely, *P. suturalis* or *P. lineata* of southern and western Moorea. The discussion narrows down, then, to these three species, *nodosa*, *filosa*, and *suturalis*, and two hypotheses as to their inter-relationships present themselves.

The first is that *P. nodosa* is derived from individuals of the Moorean *P. suturalis*, introduced into the western sector of Tahiti by human agency. Once established, migrants to other localities would extend the range of the species, as we have shown. In this case, *P. filosa* would scarcely be a relative of *nodosa* and a product of this newly introduced stock, for it would be just as difficult for snails to cross the island from Punaruu to Pirai Valley as to accomplish the reverse journey; and, furthermore, *nodosa* has not been able to populate more than a small territory outside of its original headquarters. Such a view as to the relationship between *nodosa* and *suturalis* might simplify the problem of the former's origin, but it would still leave the ancestry of the latter to be determined; it would be conceivable also that the opposite might be the actual case, namely, that *nodosa* is ancestral to *suturalis* by human means of introduction from Tahiti to Moorea, which, if true, would still leave the Tahitian problem unsolved. Finally, human intervention has not been demonstrated as a constant or even as a casual factor in the dissemination of species of *Partula*. It is certainly not more likely that *nodosa* would be humanly introduced into Moorea, or *suturalis* into Tahiti, when each species is absent from valleys of its own island located not far distant from the colonies actually existing, whose lower parts are continually visited back and forth by natives.

By an alternative hypothesis, the facts may be interpreted more reasonably. According to this, *P. nodosa* is descended from an ancient widespread stock, differing from the progenitors of other Tahitian and Moorean species that existed throughout the land-mass which included the now separate islands in question. This stock differentiated into the more immediate ancestors of *nodosa* in Tahiti and *suturalis* in Moorea. At first the *nodosa* series extended widely around Tahiti, but subsequently the colonies living in most of the valleys lost their vigor and disappeared, as certain colonies of *P. hyalina* and of other species seem to have done more recently. *P. filosa* is a local relic of the same original stock, if we regard its resem-

blance to *P. nodosa* as indicative of a genetic relationship. The latter species became very narrowly restricted in its habitat, probably to the single valley of Punaruu, but *most recently* it has revived in strength and increased in numbers, so as to occupy the seven valleys of its present range.

II. *Partula nodosa* is not uniform throughout its range, but varies from valley to valley; the local types group themselves so as to form four well-marked varieties with definite geographical limits. The individual peculiarities of the seven colonies have been described in the foregoing pages; variation has been shown (1) as regards the relative numbers of the species in the representative valley collections; (2) in the proportionate numbers of dextral and sinistral individuals; (3) in the varying frequency of the principal color-types, and (4) in the measurements and proportions of the shells as defined by statistical determinations. It is unnecessary at this point to review the details under the first three heads, but the fourth category needs to be re-examined.

The statistical constants of the seven morphological characters, for all valleys, are brought together in table 53. To facilitate the direct comparison of the valley series, the differences noted in passing from Taapuna progressively to the other valleys are given for the mean values in table 54; the significance of any difference may be estimated by its proportion to its probable error. Finally, the graphic representation of table 55 makes it possible to appreciate at a glance the degrees of change in passing from one valley to the next in both the average values and in the ranges of variation of the several characters.

We may take first the qualities of the shell as a whole. The dextral Taapuna shells are certainly longer and wider than those of Punaruu; as the excess in length is more considerable than the difference in width, the proportions are much more slender than in Punaruu. The sporadic shells of Taapuna may be disregarded in this comparison. Passing now to Maruapoo, we may restrict our attention to the 28 dextral shells, or we may base our comparison on the conditions of the prevalent sinistral type, but the two form-classes are not certainly different from one another except in shell proportions. Specifically, the Maruapoo shells are about as long as those of Punaruu, but they are certainly narrower; hence they are more slender to a degree that is statistically significant. The little specimens from Atehi are distinctively reduced in width, but far more abbreviated in length; hence they are proportionately stout—by far the stoutest of all the valley colonies. Papehū has longer shells that are broader also, but the reduction in proportions which is correlated in part with the increase in length is not commensurate with the degree of change in the latter character; this is not statistically different from the figure for the Atehi shells. The Aoua colony is shorter, narrower, and *more slender*, proving that reduction in length does not always bring about a stouter shell. Finally, the short series from Orofere comprises greatly elongated and widened individuals of slender proportions, all three differences from the Aoua colony being statistically significant.

TABLE 55  
of the cc  
range of

1                      2  
*composita*  
Taapuna V.              Punaruu V.

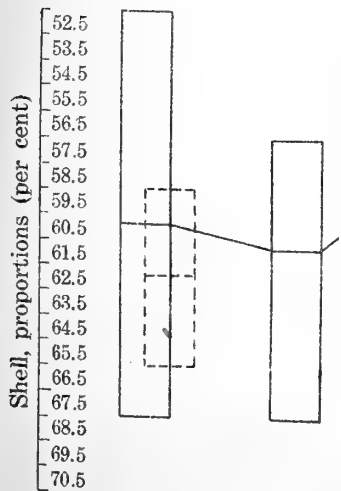
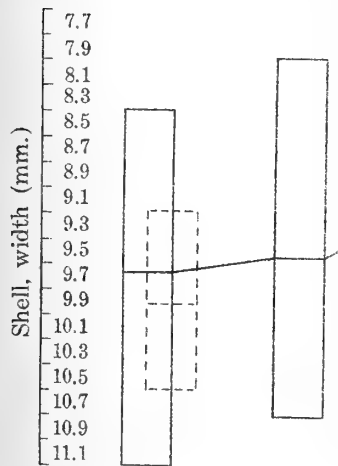
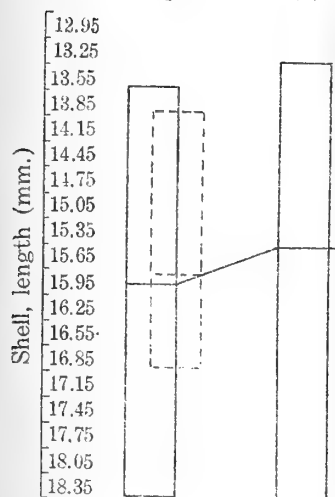
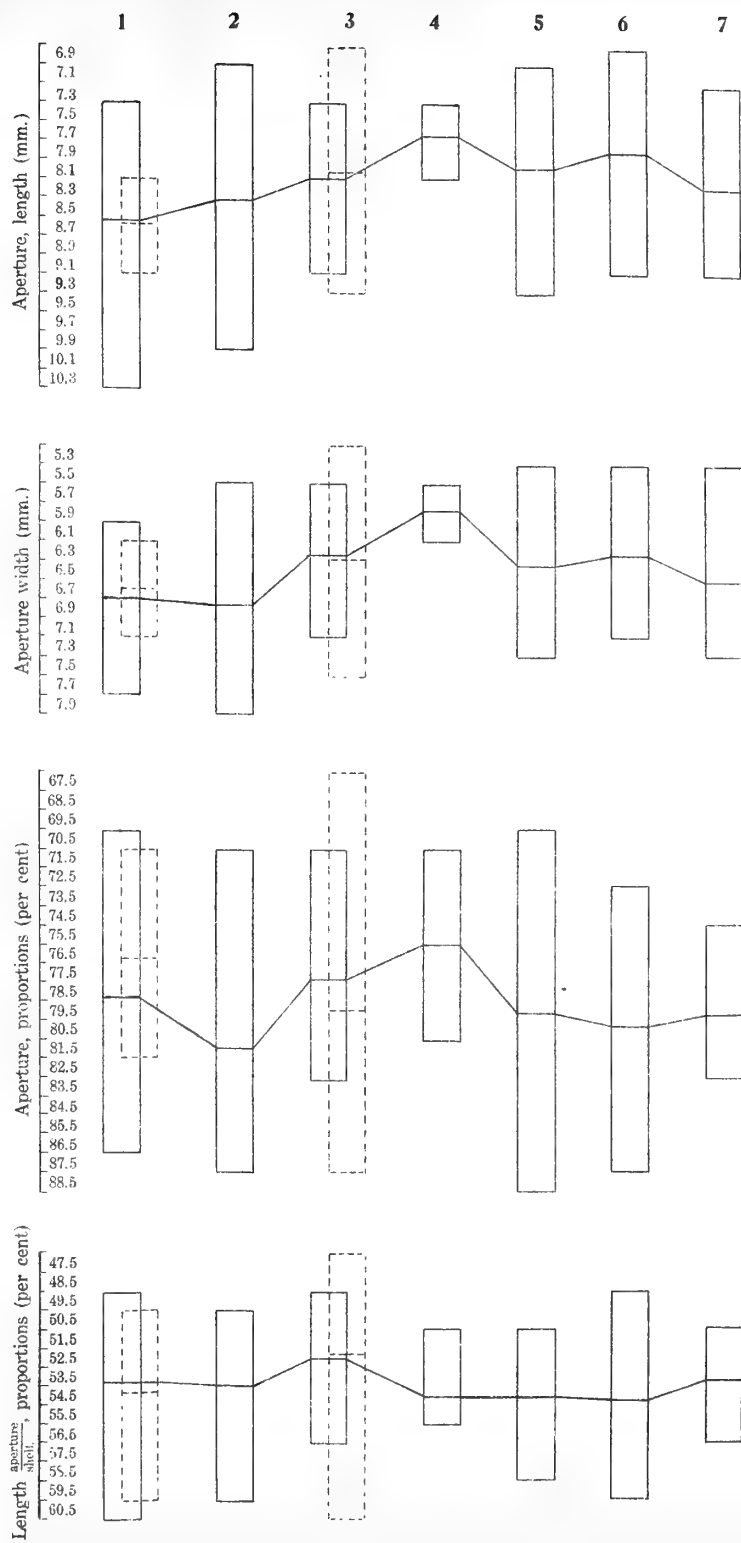
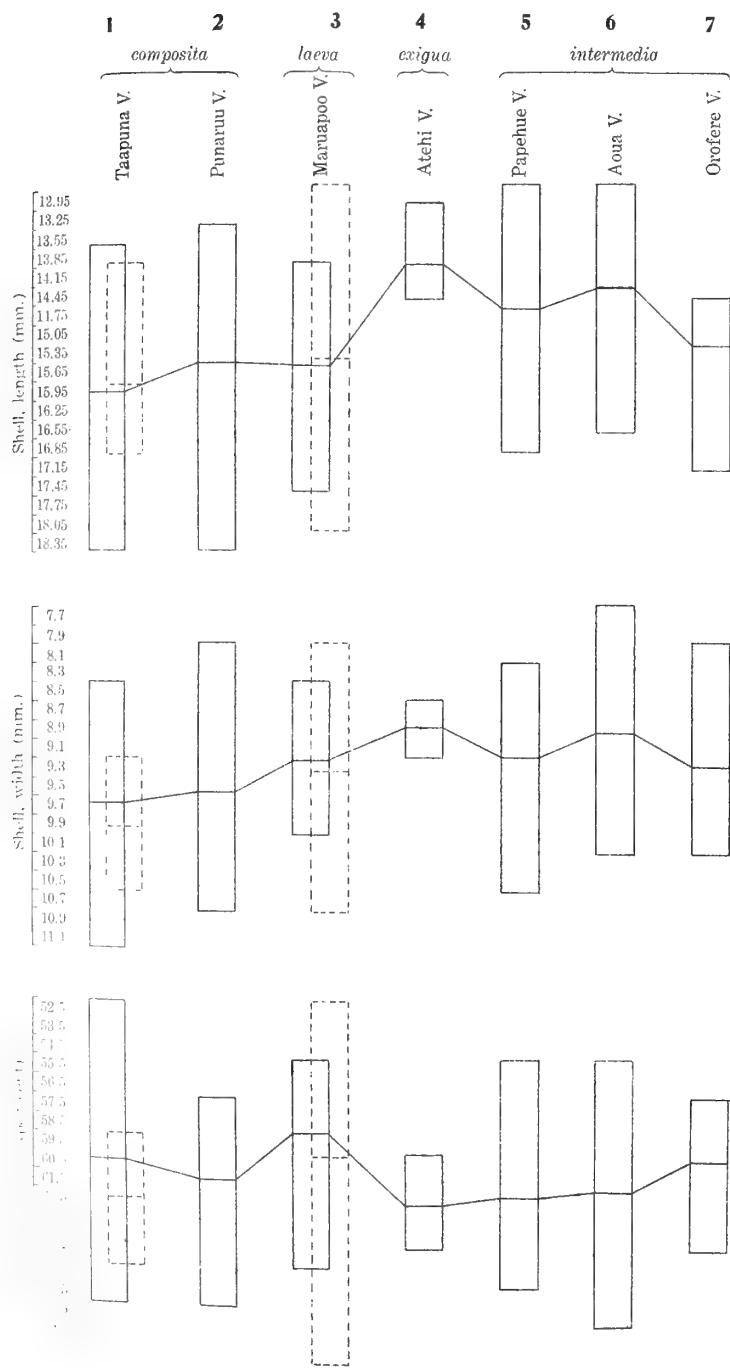






TABLE 55. *Partula nodosa*. Progressive comparison of the colonies in geographical order as regards the range of variation and the average value.





Coming now to the characters of the aperture, we find some correspondence with the above comparative results. For example, in passing from Taapuna to Punaruu, the length is reduced, but the width increases, bringing about a great increase in the degree of stoutness. Going to Maruapoo, a distinct drop in proportion is noted, as in the whole shell, due to a decrease in width that is relatively greater than the reduction in aperture length. The Atehi shells do not exhibit the same agreement; true, they are shorter and narrower in the aperture dimensions as compared with the shells of neighboring valleys, but the reduction in the second

TABLE 53.—*Partula nodosa*. Comparison of valley colonies.

MEAN VALUE.								
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.	
		mm.	mm.	p. ct.	mm.	mm.	p. ct.	p. ct.
Taapuna, dex. . .	298	15.9933 ± .0320	9.6604 ± .0170	60.3188 ± .0820	8.6215 ± .0179	6.8013 ± .0128	78.8356 ± .1053	53.7953 ± .0705
Taapuna, sin. . .	6	15.9000 ± .2673	9.9000 ± .1350	62.3333 ± .5372	8.6333 ± .0936	6.6667 ± .0866	76.8333 ± .9360	54.3333 ± .3693
Punaru, dex. . .	160	15.5769 ± .0468	9.5637 ± .0245	61.3625 ± .0986	8.4212 ± .0248	6.8650 ± .0207	81.4875 ± .1382	53.9250 ± .0899
Maruapoo, dex. .	28	15.6072 ± .1113	9.2215 ± .0583	58.9286 ± .2879	8.2000 ± .0599	6.3786 ± .0459	77.8572 ± .3560	52.4286 ± .2070
Maruapoo, sin. .	649	15.5497 ± .0196	9.3409 ± .0107	60.0439 ± .0642	8.1539 ± .0107	6.3922 ± .0100	79.3968 ± .0812	52.2412 ± .0484
Atehi, dex. . . .	4	14.0750 ± .2225	8.8500 ± .0559	62.7500 ± .6021	7.7500 ± .0876	5.8500 ± .0559	76.0000 ± 1.1316	54.5000 ± .5841
Papeh, dex. . . .	205	14.7647 ± .0311	9.2044 ± .0187	62.3292 ± .0911	8.0717 ± .0173	6.4210 ± .0142	79.5780 ± .1150	54.5192 ± .0707
Aoua, dex. . . .	382	14.4249 ± .0231	8.9492 ± .0141	61.9424 ± .0750	7.9058 ± .0131	6.3519 ± .0108	80.2146 ± .0872	54.6544 ± .0545
Orofere, dex. . .	18	15.3667 ± .1899	9.2889 ± .1014	60.3889 ± .2798	8.2778 ± .0988	6.6111 ± .1018	79.8333 ± .3594	53.7778 ± .2531
All, dex. . . . .	1,095	15.1281 ± .0206	9.2925 ± .0106	61.3886 ± .0452	8.2200 ± .0103	6.5652 ± .0083	79.8388 ± .0758	54.2169 ± .0349
STANDARD DEVIATION.								
Taapuna, dex. . .	298	0.8211 ± .0227	0.4353 ± .0120	2.1016 ± .0580	0.4580 ± .0126	0.3556 ± .0098	2.6975 ± .0744	1.8060 ± .0498
Taapuna, sin. . .	6	.9709 ± .1890	.4899 ± .0095	1.9508 ± .3799	.3399 ± .0662	.3144 ± .0612	3.3993 ± .0662	2.7938 ± .2611
Punaru, dex. . .	160	.8783 ± .0331	.4596 ± .0173	1.8488 ± .0697	.4654 ± .0175	.3883 ± .0146	2.5908 ± .0977	1.6865 ± .0636
Maruapoo, dex. .	28	.8736 ± .0787	.4578 ± .0412	2.2588 ± .2035	.4705 ± .0424	.3599 ± .0324	2.7930 ± .2517	1.6241 ± .1464
Maruapoo, sin. .	649	.7407 ± .0139	.4061 ± .0076	2.4239 ± .0454	.4027 ± .0076	.3783 ± .0071	3.0678 ± .0565	1.8246 ± .0342
Atehi, dex. . . .	4	.4918 ± .1573	.1658 ± .0395	1.7853 ± .4258	.2598 ± .0619	.1658 ± .0395	3.3556 ± .8002	1.7320 ± .4130
Papeh, dex. . . .	205	.6598 ± .0220	.3978 ± .0132	1.9343 ± .0644	.3693 ± .0122	.3024 ± .0100	2.4422 ± .0813	1.5004 ± .0500
Aoua, dex. . . .	382	.6707 ± .0163	.4079 ± .0100	2.1708 ± .0530	.3795 ± .0093	.3126 ± .0076	2.5242 ± .0617	1.5769 ± .0385
Orofere, dex. . .	18	1.1945 ± .1343	.6376 ± .0717	1.7603 ± .1978	.6214 ± .0699	.6402 ± .0720	2.2608 ± .2541	1.5918 ± .1790
All, dex. . . . .	1,095	1.0097 ± .0146	.5201 ± .0075	2.2158 ± .0320	.5059 ± .0073	.4086 ± .0059	2.7374 ± .0536	1.7149 ± .0247

TABLE 54.—*Partula nodosa*. Progressive comparison, by valleys, of dextral groups. Differences in mean value.

Valley.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.
	Length.	Width.	Proportions.	Length.	Width.	Proportions.	
	mm.	mm.	p. ct.	mm.	mm.	p. ct.	p. ct.
Taapuna. . .	−0.4164 ± .0567	−0.0967 ± .0298	+1.0437 ± .1286	−0.2003 ± .0305	+0.0637 ± .0243	+2.6519 ± .1737	[+ .1297 ± .1142]
Punaru. . .	[+ .0303 ± .1215]	−.3422 ± .0632	−2.4339 ± .3043	−.2212 ± .0648	−.4864 ± .0503	−3.6303 ± .3819	−1.4964 ± .2257
Maruapoo. .	−1.5019 ± .2487	−.3715 ± .0807	+3.8214 ± .6674	−.4500 ± .1062	−.5286 ± .0723	[−1.8572 ± 1.1862]	+2.0714 ± .6197
Atehi. . . . .	+ .6897 ± .2246	+ .3544 ± .0589	[−.4208 ± .6089]	+ .3217 ± .0893	+ .5710 ± .0576	+3.5780 ± 1.1374	[+ .0192 ± .5883]
Papeh. . . .	−.3398 ± .0387	−.2552 ± .0234	−.3868 ± .0996	−.1659 ± .0217	−.0691 ± .0178	+ .6366 ± .1443	[+ .1352 ± .0892]
Aoua. . . . .	+ .9418 ± .1913	+ .3397 ± .1023	−1.5535 ± .2897	+ .3728 ± .0996	+ .2592 ± .1023	[−.3813 ± .3698]	−.8766 ± .2589
Orofere. . . .							

respect is so great as to make the proportionate measure the lowest average in the whole series of colonies. The comparison of Papehue, Aoua, and Orofere specimens brings out essentially the same relations that appear when the shells as wholes are compared.

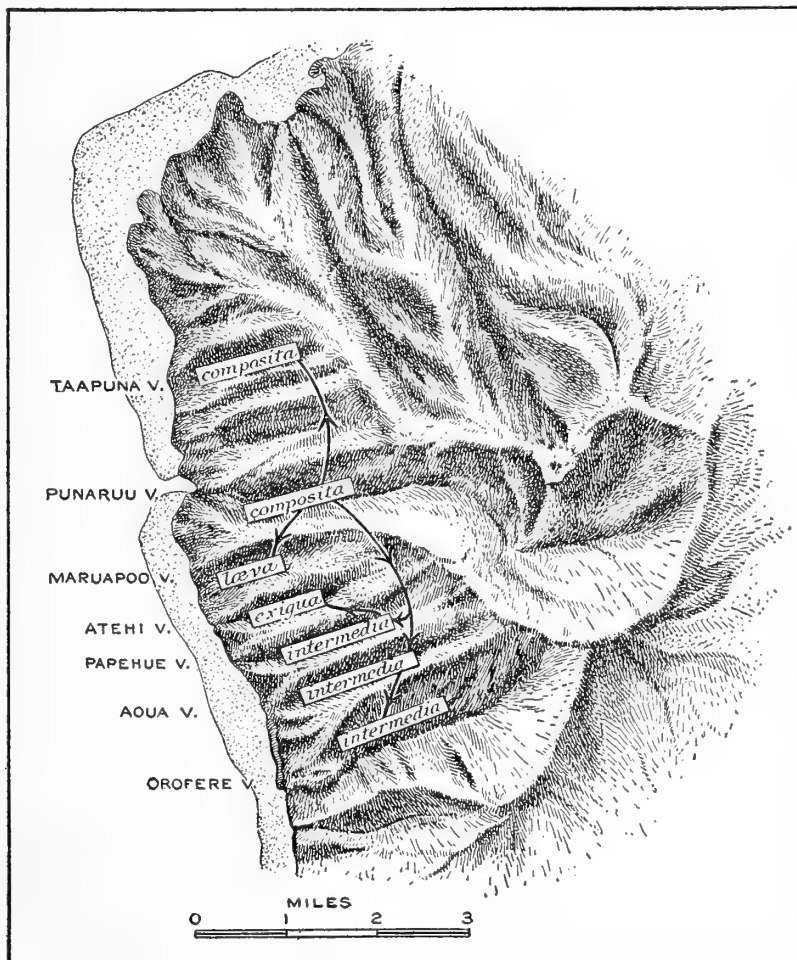
Finally, we may deal briefly with the proportion of aperture length to shell length. The "curve" of averages changes from valley to valley, like those of the foregoing characters. Its most interesting movement focuses about Maruapoo, where the shell length remains about what it was in Punaruu, while the aperture dimension decreases greatly; the result is a marked drop in the relative figure to the lowest average of the whole series of valley colonies.

In brief, the statistical constants of the seven characters vary from colony to colony, to some extent in correlation, but not always in close correspondence. A relative reduction in shell length is not necessarily accompanied by a drop in aperture length or by an increase in shell proportions. Each valley bears a population with characteristic features.

Now we may take into account the characteristics of color displayed by the shells of the seven colonies, which were ignored in the above statistical summary. It then appears that there are not seven independent and coequal types, each restricted to a single valley, but that only four primary divisions exist, as the detailed description has shown. The shells of Taapuna and Punaruu form together the primary variety *composita*, so called because its members fall into four well-marked color-classes to which individual names of a secondary order have been given, *e. g.*, *pallidior*, *trilineata*, *concrescens*, and *nodosa*; an additional feature of this variety is the dextral coil, which is predominant (Taapuna) or virtually exclusive (Punaruu). In Maruapoo most of the shells differ from var. *composita* and the succeeding geographically circumscribed groups in statistical peculiarities, in coloration, and in the prevalent sinistral coil; for these reasons they require a distinctive varietal name, *laeva*, chosen on account of the last-named character. As a group, although a small one, the shells of Atehi are minute, very stout, dextral, and plain brown; their small size is specified by the varietal name, *exigua*. Finally, the three valleys of Papehue, Aoua, and Orofere are inhabited by snails of this species that resemble *composita* in color-constitution, but their statistical characters and their geographical discontinuity set them apart from *composita*, as well as from *laeva* and *exigua* for indicated reasons. Because a few of the shells in Papehue and Aoua approach the condition of *exigua*, this last section of *P. nodosa* has been called var. *intermedia*.

At this point we must deal with a question which has been held in abeyance heretofore, namely, whether the differentiation into color-classes, as in the colonies of Taapuna and Aoua, is *more* or *less* fundamental than the division into geographically circumscribed groups which have been designated as primary varieties. Are *pallidior*, *trilineata*, etc., the real varieties and elementary species, represented by varying proportionate numbers in different valleys where, also, the details of ground-colors and patterns have changed, or are *composita*, *laeva*, *exigua*, and *intermedia* the primary divisions of the species in the sense that they are more differentiated *inter se* than are their constituent color-classes? One consideration alone would lead us to regard the second classification as primary, and the former as subordinate.

This is the fact that the color-varieties as they exist in Punaruu and elsewhere are not *physiologically distinct*; the evidence afforded by the embryonic shells proves conclusively that they do not breed exactly true, but interbreed to some extent. The groups called *composita*, *lava*, etc., can not interbreed, excepting in so far as migrants may make their way from one valley to another—something which can be accomplished only with the lapse of long time. In short, the varieties that are circumscribed geographically, and are distinguished as well by their characteristic details of color and form, are *primary* in the sense that they are more differentiated than color varieties living in the same valley. It may be that color differentiation preceded in time the division here regarded as paramount, accomplished in the course of emigration to new localities, but as the facts stand, that diversification which includes the element of geographical discontinuity is more fundamental as it leads more directly to true differentiation of specifically separated forms.



TEXT-FIG. 6.—Topographical chart of the region inhabited by *Partula nodosa*, showing the present locations of the several primary varieties and the probable lines of their ancestral migrations.

III. *The internal evidence as to genetic relationships indicates that var. composita is directly ancestral to var. lava and var. intermedia, and indirectly through the latter to var. exigua* (text-fig. 6). This follows from the facts of resemblance and difference

as given in the detailed analysis. It has been shown earlier that the original headquarters of *nodosa* centered in Punaruu Valley, on the basis of evidence entirely independent of Garrett's statements. Here and in Taapuna the species has retained what is no doubt an original composite character, though the Taapuna colony differs from the other in its frequent production of sinistral sports. Maruapoo seems to have been populated directly from Punaruu; it may be that the first snails to enter this ravine by traversing the interposed ridge were sinistral, but as only one in 200 from Punaruu was sinistral in Garrett's time it is more probable that the original colonists were dextral, or at least mixed, and that their offspring gradually lost the direct twist and also changed somewhat in details of color and color-pattern. The variety called *intermedia*, in Papehue, Aoua, and Orofere, is obviously more nearly related to *composita* than to *læva*, for it would have arisen from the latter only by completely reverting to the original conditions in color and coil. It is more probable that this variety is descended from migrants from the upper part of Punaruu, from which the line of advance, if followed directly, would pass the heads of both Maruapoo and Atehi. In each of the three valleys of the range, the colony of *intermedia* has assumed distinctive characters, both in structural respects and in the proportionate numbers of the constituent color-classes; rarely a sinistral sport is produced. Finally, var. *exigua* is so like the small-sized and plain shells in Papehue and Aoua as to indicate its origin from the latter by a short northward migration. Certainly it has nothing in common with *læva* of near-by Maruapoo and it is unlikely that it has arisen by direct migration into Atehi from Punaruu, for none of the members of var. *composita* deviate in the direction of *exigua*.

IV. *The rôle of the environment in the differentiation of P. nodosa seems to be negligible.* On this point, no extended argument is necessary. The production of differing color-varieties (*pallidior*, *concrescens*, etc.) in one and the same valley could scarcely be attributed to environmental factors as causal agents, for these are certainly the same in one locality. We can not say that var. *læva* owes its sinistrality to peculiar external conditions of Maruapoo when dextral shells occur in the same place. The small size and dextral form of *exigua* can not be referred to an adverse or otherwise factorial environment in Atehi, because *P. hyalina* and *P. clara* flourish here in no depauperate condition, while the variety of *P. otaheitana* that also occurs is numerous, well developed, and invariably sinistral; one and the same environment is not likely to produce such diverse results *by itself*.

It would seem, then, that the constitutional characters of the first migrants into a previously unpopulated valley would be the real determining causes for the basic differential characters of their descendants, which would subsequently vary, but not on account of a qualitative effect of the environment.

## CHAPTER VII.

### PARTULA OTAHEITANA Bruguière.

#### GENERAL CONSIDERATIONS.

By far the greater part of the *Partula* population of Tahiti consists of representatives of *P. otaheitana* Bruguière, which exists in one or in several of its manifold forms in all of the valleys of Tahiti explored in the course of the present investigation where any snails whatsoever were secured. Undoubtedly the species occurs in some of the smaller ravines, where, however, the shallow vertical depth of the valley, the lack of deep shade, relative dryness, and the scarcity of decaying succulent plants render its situation precarious and its numbers few. There is good reason to believe, nevertheless, that all of the variations of this species are represented in the collections of the present research; these comprise more than 20,000 adults and 6,000 adolescents, together with several thousand embryonic snails dissected out from their parents, which were sufficiently advanced in development to show many of their specific and varietal characters.

The wealth of material renders it possible to make an exhaustive analysis of the colonies living in different areas. The circumstances are such as to make this species more valuable than any other for the purposes of the present research; indeed, its analysis forms the surest basis for the views herein and hereafter expressed as to the relative values of hereditary and environmental factors in the evolution of the several species constituting the whole genus. It is true that through the study of *P. hyalina*, *P. clara*, and *P. nodosa* definite conclusions are established, all the more readily because those forms are relatively simple as regards their intrinsic diversifications and their geographical range; but all of the relations that they display are repeated in *P. otaheitana*, amplified to the fullest possible degree, while others are added. In brief, the favorable conditions are (1) the existence of the species in practically all habitable areas of the island; (2) the large numbers obtainable in nearly every valley; and (3) its extraordinary differentiation into varieties of primary, secondary, and tertiary degree, as a result of which it has become the most complex of the known species of *Partula*.

The incidental comparison with the situation of former decades as depicted by earlier writers is made somewhat difficult and at times impossible by the existing confusion in the taxonomy of the species as a whole. From fifteen to twenty *specific* names have been given to the various "forms" of *P. otaheitana* by systematists who (with the exception of Garrett and Mayer and those who have relied upon their explicit statements) have been wholly ignorant or neglectful of the exact localities in Tahiti from which their "types" were obtained. Data of this kind are absolutely indispensable, and Garrett's monograph places the student of distribution under great obligations because the forms he distinguishes and describes are invariably located with substantial accuracy. While it is true that some slight errors may be detected, these no doubt arose because of the lack of complete maps

in Garrett's time; but such errors do not materially affect the fundamental value of the monograph in question. Pilsbry has followed Garrett's description in its essential features and has quoted the geographical details at length.

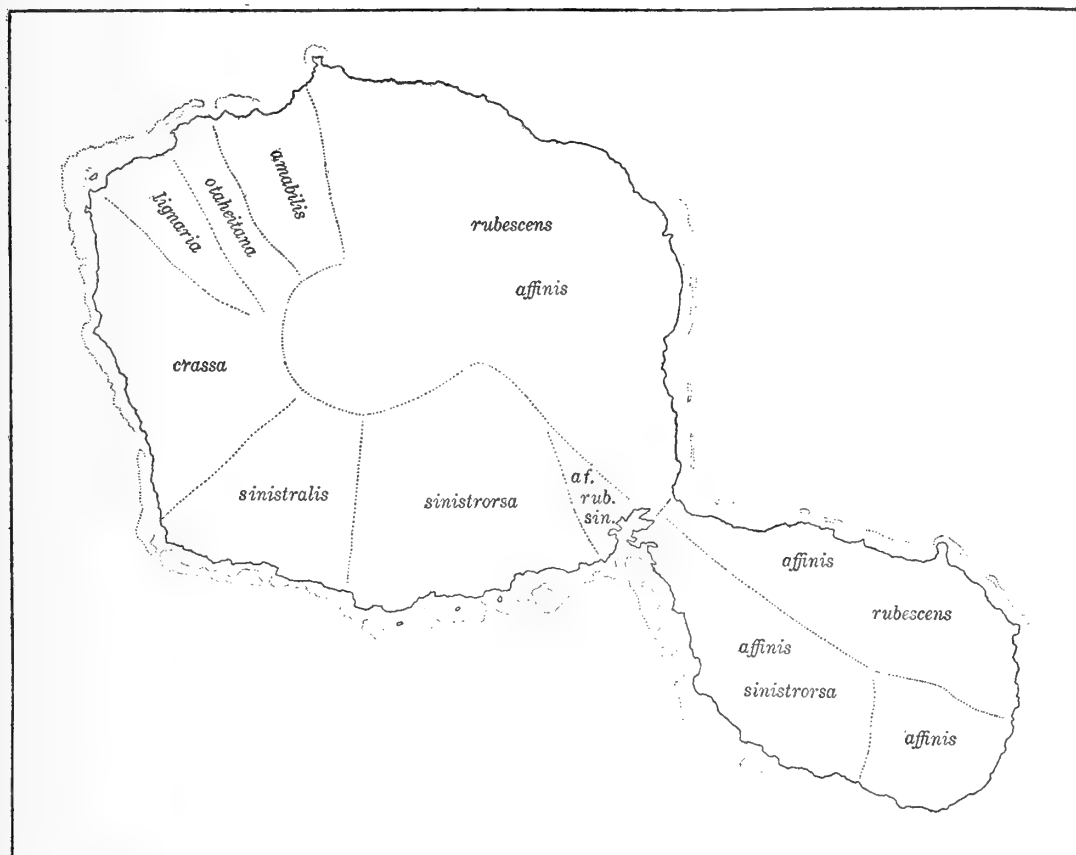
Mayer's illuminating study of 1899, confirming the observations of Garrett as regards the inhabitants of six valleys, for the first time showed how important for the problems under consideration were the young snails harbored by the gravid adults. The additional value of Mayer's results inheres in the fact that he describes an intermediate period between the time of Garrett's original and basic discoveries and the present; the intermediate condition is especially significant in the case of the Fautaua colony, on account of the taxonomic and biological primacy of the shells of that association.

In describing the abundant material of this species, it will be necessary to take many things into account and to enter into considerable detail. First of all, primary varieties and their subordinate modifications must be described and distinguished, and referred wherever possible to earlier defined types. But a primary variety can not be treated solely by itself without entering into detailed specifications regarding the geographical location of its headquarters and of its outlying representatives. On the other hand, it would not be justifiable to follow the species as a whole from valley to valley, for such a course would involve the parallel consideration often of two, and sometimes of three, principal varieties, and would thus lead to inevitable confusion. In the present account a combination is made of the two orders of description, namely, the geographical and the systematic; at the outset the primary taxonomic divisions of the species will be described briefly, and then each of these will be taken up and followed throughout its geographical range, regardless of other forms of the species that may accompany it.

It is necessary to add a further preliminary word regarding the general analysis that follows. This species is very complex and variable, but as a whole it is absolutely discontinuous with any other, such as *P. nodosa*. Its members fall into groups that are relatively but not absolutely discontinuous; and if the whole *otaheitana* series be taken as a single species, then such component groups are properly designated *primary varieties*, like the corresponding major divisions of *P. clara* and *P. nodosa*. But in contrast with the situation as described for those species, this case differs in that the primary subdivisions of *P. otaheitana* are far more clearly differentiated *inter se*, while in addition each of them is more or less resolved into geographically circumscribed secondary varieties; these last often may be more diverse than the primary varieties of another species like *P. nodosa*. Hence instead of viewing the whole *otaheitana* series as one compound species, with almost equal propriety we might regard it as a group of species which do not differ from one another as much as each of them does from *P. nodosa*, *P. filosa*, etc. The essential points, however, are the close genetic relationships of the groups here called primary varieties, and their collective demarcation from other species. Consequently, we shall treat this case as one involving a single species, *P. otaheitana*, in which differentiation has been carried to a far greater degree than in any other instance.



The following brief outline and the census table of the species as it is represented in my own collections (table 56), together with the simple outline chart (fig. 7), give the essential facts relating to the *primary varieties* of *P. otaheitana* and to their areas of occupation.



TEXT-FIG. 7.—Chart showing the present distribution of the primary varieties of *Partula otaheitana*.

A. The most generalized representatives of the species exist in Fautaua Valley, in the northern sector of Tahiti nui. This large and justly famed valley is near the harbor where the ships of the earlier voyagers remained at anchor, and there is little doubt that the first shells of the species came from this region, for the original description of Bruguière applies more closely to the specimens from Fautaua than to those of any other colony. Sinistral examples are specified in his account and hence they are regarded as more typical than the dextral snails, but at the present time the latter almost equal the former in abundance. It is permissible to distinguish the Fautaua colony as *P. otaheitana otaheitana*, and it is a curious coincidence that it is not only the first-discovered but also the most generalized group, standing virtually in an ancestral relation to all of the other varieties. This basic position is accorded on the following grounds: It includes both sinistral and dextral forms; members of each of these classes produce young of the contrasted coil; in each class the shells range from large to small; in each class, also, a wide range in color is exhibited, from light yellowish or whitish shells to reddish-yellow,

TABLE 56.—*Partula otaheitana*. Census of primary varieties.

Valley.	Numbers of adult individuals, sinistral and dextral.																
	Total.	<i>otaheitana</i> .		<i>amabilis</i> .		<i>rubescens</i> .		<i>affinis</i> .		<i>sinistrorsa</i> .		<i>sinistralis</i> .		<i>crassa</i> .		<i>lignaria</i> .	
		Sin.	Dex.	Sin.	Dex.	Sin.	Dex.	Sin.	Dex.	Sin.	Dex.	Sin.	Dex.	Sin.	Dex.	Sin.	Dex.
Fautaua.....	955	526	429	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Hamuta.....	474	...	...	299	175	...	...	...	...	...	...	...	...	...	...	...	...
Pirai.....	988	...	...	988	...	...	...	...	...	...	...	...	...	...	...	...	...
Pohaitara.....	387	...	...	387	...	...	...	...	...	...	...	...	...	...	...	...	...
Ururoa.....	345	...	...	344	1	...	...	...	...	...	...	...	...	...	...	...	...
Tuauru.....	374	...	...	...	...	8	3	363	...	...	...	...	...	...	...	...	...
Ahonu.....	295	...	...	...	...	146	3	146	...	...	...	...	...	...	...	...	...
Faaripoo.....	312	...	...	...	...	2	...	310	...	...	...	...	...	...	...	...	...
Papenoo.....	502	...	...	...	...	342	7	153	...	...	...	...	...	...	...	...	...
Farapa.....	591	...	...	...	...	...	...	591	...	...	...	...	...	...	...	...	...
Faarumai.....	353	...	...	...	...	19	...	334	...	...	...	...	...	...	...	...	...
Tiarei.....	166	...	...	...	...	15	...	151	...	...	...	...	...	...	...	...	...
Mahaena.....	147	...	...	...	...	6	4	137	...	...	...	...	...	...	...	...	...
Vahii.....	409	...	...	...	...	...	...	409	...	...	...	...	...	...	...	...	...
Paraura.....	668	...	...	...	...	89	...	579	...	...	...	...	...	...	...	...	...
Faatautia.....	12	...	...	...	...	...	...	12	...	...	...	...	...	...	...	...	...
Papeiha.....	275	...	...	...	...	112	...	163	...	...	...	...	...	...	...	...	...
Utuufai.....	347	...	...	...	...	5	...	342	...	...	...	...	...	...	...	...	...
Faone.....	594	...	...	...	...	2	...	592	...	...	...	...	...	...	...	...	...
Tehoro.....	306	...	...	...	...	1	...	305	...	...	...	...	...	...	...	...	...
Haavini.....	273	...	...	...	...	214	3	56	...	...	...	...	...	...	...	...	...
Tautira.....	289	...	...	...	...	82	...	207	...	...	...	...	...	...	...	...	...
Aionifaa.....	15	...	...	...	...	1	...	14	...	...	...	...	...	...	...	...	...
Aiurua.....	219	...	...	...	...	119	...	100	...	...	...	...	...	...	...	...	...
Vaiiau.....	16	...	...	...	...	...	5	11	...	...	...	...	...	...	...	...	...
Hototunu.....	45	...	...	...	...	...	...	45	...	...	...	...	...	...	...	...	...
Vaiaaia.....	145	...	...	...	...	...	1	5	139	...	...	...	...	...	...	...	...
Aiavaro.....	170	...	...	...	...	...	...	170	...	...	...	...	...	...	...	...	...
Vavii.....	225	...	...	...	...	...	...	6	219	...	...	...	...	...	...	...	...
Vaipoe.....	259	...	...	...	...	...	...	69	190	...	...	...	...	...	...	...	...
Haoma.....	44	...	...	...	...	...	...	44	...	...	...	...	...	...	...	...	...
Oopu.....	308	...	...	...	...	272	...	36	...	...	...	...	...	...	...	...	...
Apirimaue.....	291	...	...	...	...	1	...	6	284	...	...	...	...	...	...	...	...
Titaviri.....	245	...	...	...	...	...	...	...	168	77	...	...	...	...	...	...	...
Tenaire.....	907	...	...	...	...	...	...	...	374	533	...	...	...	...	...	...	...
Maara.....	203	...	...	...	...	...	...	...	133	70	...	...	...	...	...	...	...
Vaihiria.....	303	...	...	...	...	...	...	...	303	...	...	...	...	...	...	...	...
Vairaharaha.....	247	...	...	...	...	...	...	...	247	...	...	...	...	...	...	...	...
Faarahi.....	467	...	...	...	...	...	...	...	465	2	...	...	...	...	...	...	...
Moaroa.....	434	...	...	...	...	...	...	...	434	...	...	...	...	...	...	...	...
Taharua.....	325	...	...	...	...	...	...	...	322	3	...	...	...	...	...	...	...
Teohu.....	459	...	...	...	...	...	...	...	...	...	459	...	...	...	...	...	...
Papeiti.....	475	...	...	...	...	...	...	...	...	...	475	...	...	...	...	...	...
Temarua.....	563	...	...	...	...	...	...	...	...	...	561	2	...	...	...	...	...
Vaipoo.....	62	...	...	...	...	...	...	...	...	...	62	...	...	...	...	...	...
Tearatapu.....	30	...	...	...	...	...	...	...	...	...	30	...	...	...	...	...	...
Opiriroa.....	152	...	...	...	...	...	...	...	...	...	152	...	...	...	...	...	...
Otuna.....	347	...	...	...	...	...	...	...	...	...	347	...	...	...	...	...	...
Maruia.....	129	...	...	...	...	...	...	...	...	...	104	25	...	...	...	...	...
Tereehia.....	130	...	...	...	...	...	...	...	...	...	70	60	...	...	...	...	...
Tiamao.....	326	...	...	...	...	...	...	...	...	...	177	149	...	...	...	...	...
Vaipuarai.....	180	...	...	...	...	...	...	...	...	...	180	...	...	...	...	...	...
Vaitupa.....	321	...	...	...	...	...	...	...	...	...	...	...	...	321	...	...	...
Atitara.....	154	...	...	...	...	...	...	...	...	...	...	...	...	153	1	...	...
Orofero.....	197	...	...	...	...	...	...	...	...	...	...	...	...	197	...	...	...
Aoua.....	650	...	...	...	...	...	...	...	...	...	...	...	...	650	...	...	...
Papehue.....	143	...	...	...	...	...	...	...	...	...	...	...	...	143	...	...	...
Atehi.....	413	...	...	...	...	...	...	...	...	...	...	...	...	413	...	...	...
Maruapoo.....	135	...	...	...	...	...	...	...	...	...	...	...	...	135	...	...	...
Punaruu.....	557	...	...	...	...	...	...	...	...	...	...	...	...	557	...	...	...
Taapuna.....	225	...	...	...	...	...	...	...	...	...	...	...	...	225	...	...	...
Tipaerui.....	937	...	...	...	...	...	...	...	...	...	...	...	...	...	...	24	913
Total.....	20,515	526	429	2,018	176	1,436	...	26	5,186	3,448	685	2,617	236	2,794	1	24	913
		955		2,194		1,436		5,212		4,133		2,853		2,795		937	

TABLE 56.—*Partula otaheitana*. Census of primary varieties—Continued.

Valley.	Per cent of valley collections of <i>P. otaheitana</i> .															
	<i>otaheitana</i> .		<i>amabilis</i> .		<i>rubescens</i> .		<i>affinis</i> .		<i>sinistrorsa</i> .		<i>sinistralis</i> .		<i>crassa</i> .		<i>lignaria</i> .	
	Sin.	Dex.	Sin.	Dex.	Sin.	Dex.	Sin.	Dex.	Sin.	Dex.	Sin.	Dex.	Sin.	Dex.	Sin.	Dex.
Fautaua.....	55.1	44.9	....	....	....	..	....	....	....	....	....	....	....	....	..	....
Hamuta.....	....	....	63.0	36.9	....	..	....	....	....	....	....	....	....	....	..	....
Pirai.....	....	....	100	....	....	..	....	....	....	....	....	....	....	....	..	....
Pohaitara.....	....	....	100	....	....	..	....	....	....	....	....	....	....	....	..	....
Ururoa.....	....	....	99.7	0.3	....	..	....	....	....	....	....	....	....	....	..	....
Tuauru.....	....	....	....	....	2.1	..	0.8	97.0	....	....	....	....	....	....	..	....
Ahonu.....	....	....	....	....	49.4	..	1.1	49.4	....	....	....	....	....	....	..	....
Faaripoo.....	....	....	....	....	0.6	..	..	99.4	....	....	....	....	....	....	..	....
Papenoo.....	....	....	....	....	68.1	..	1.4	30.5	....	....	....	....	....	....	..	....
Farapa.....	....	....	....	....	....	..	....	100	....	....	....	....	....	....	..	....
Faarumai.....	....	....	....	....	5.3	..	....	94.6	....	....	....	....	....	....	..	....
Tiarei.....	....	....	....	....	9.0	..	....	91.0	....	....	....	....	....	....	..	....
Mahaena.....	....	....	....	....	4.1	..	2.7	93.1	....	....	....	....	....	....	..	....
Vahii.....	....	....	....	....	....	..	....	100	....	....	....	....	....	....	..	....
Paraura.....	....	....	....	....	13.3	..	....	86.6	....	....	....	....	....	....	..	....
Faatautia.....	....	....	....	....	....	..	....	100	....	....	....	....	....	....	..	....
Papeiha.....	....	....	....	....	40.7	..	....	59.3	....	....	....	....	....	....	..	....
Utuufai.....	....	....	....	....	1.4	..	....	98.5	....	....	....	....	....	....	..	....
Faone.....	....	....	....	....	0.3	..	....	99.6	....	....	....	....	....	....	..	....
Tehoro.....	....	....	....	....	0.3	..	....	99.7	....	....	....	....	....	....	..	....
Haavini.....	....	....	....	....	78.4	..	1.1	20.5	....	....	....	....	....	....	..	....
Tautira.....	....	....	....	....	28.4	..	....	71.6	....	....	....	....	....	....	..	....
Aionifaa.....	....	....	....	....	6.6	..	....	93.3	....	....	....	....	....	....	..	....
Aiurua.....	....	....	....	....	54.3	..	....	45.6	....	....	....	....	....	....	..	....
Vaiau.....	....	....	....	....	....	..	31.2	68.7	....	....	....	....	....	....	..	....
Hototunu.....	....	....	....	....	....	..	....	100	....	....	....	....	....	....	..	....
Vaiaia.....	....	....	....	....	....	..	0.7	3.4	95.8	....	....	....	....	....	..	....
Aiavaro.....	....	....	....	....	....	..	....	....	100	....	....	....	....	....	..	....
Vavii.....	....	....	....	....	....	..	....	2.7	97.3	....	....	....	....	....	..	....
Vaipoe.....	....	....	....	....	....	..	....	26.6	73.3	....	....	....	....	....	..	....
Haoma.....	....	....	....	....	....	..	....	100	....	....	....	....	....	....	..	....
Oopu.....	....	....	....	....	88.3	..	....	11.7	....	....	....	....	....	....	..	....
Apirimaue.....	....	....	....	....	0.3	..	....	2.1	97.6	....	....	....	....	....	..	....
Titaviri.....	....	....	....	....	....	..	....	....	68.5	31.4	....	....	....	....	..	....
Tenaire.....	....	....	....	....	....	..	....	....	41.3	58.6	....	....	....	....	..	....
Maara.....	....	....	....	....	....	..	....	....	65.4	34.5	....	....	....	....	..	....
Vaihiria.....	....	....	....	....	....	..	....	....	100	....	....	....	....	....	..	....
Vairaharaha.....	....	....	....	....	....	..	....	....	100	....	....	....	....	....	..	....
Faarahi.....	....	....	....	....	....	..	....	....	99.5	0.4	....	....	....	....	..	....
Moaroa.....	....	....	....	....	....	..	....	....	100	....	....	....	....	....	..	....
Taharua.....	....	....	....	....	....	..	....	....	90.0	0.9	....	....	....	....	..	....
Teohu.....	....	....	....	....	....	..	....	....	....	100	....	....	....	....	..	....
Papeiti.....	....	....	....	....	....	..	....	....	....	100	....	....	....	....	..	....
Temarua.....	....	....	....	....	....	..	....	....	....	99.5	0.4	....	....	....	..	....
Vaipoo.....	....	....	....	....	....	..	....	....	....	100	....	....	....	....	..	....
Tearatapu.....	....	....	....	....	....	..	....	....	....	100	....	....	....	....	..	....
Opiriroa.....	....	....	....	....	....	..	....	....	....	100	....	....	....	....	..	....
Otuna.....	....	....	....	....	....	..	....	....	....	100	....	....	....	....	..	....
Maruia.....	....	....	....	....	....	..	....	....	....	80.6	19.4	....	....	....	..	....
Tereehia.....	....	....	....	....	....	..	....	....	....	53.8	46.1	....	....	....	..	....
Tiamao.....	....	....	....	....	....	..	....	....	....	54.2	45.7	....	....	....	..	....
Vaipuarii.....	....	....	....	....	....	..	....	....	....	100	....	....	....	....	..	....
Vaitupa.....	....	....	....	....	....	..	....	....	....	....	....	100	....	....	..	....
Atitara.....	....	....	....	....	....	..	....	....	....	....	....	99.4	0.6	....	..	....
Orofere.....	....	....	....	....	....	..	....	....	....	....	....	100	....	....	..	....
Aoua.....	....	....	....	....	....	..	....	....	....	....	....	100	....	....	..	....
Papehue.....	....	....	....	....	....	..	....	....	....	....	....	100	....	....	..	....
Atehi.....	....	....	....	....	....	..	....	....	....	....	....	100	....	....	..	....
Maruapoo.....	....	....	....	....	....	..	....	....	....	....	....	100	....	....	..	....
Punaruu.....	....	....	....	....	....	..	....	....	....	....	....	100	....	....	..	....
Taapuna.....	....	....	....	....	....	..	....	....	....	....	....	100	....	....	..	....
Tipaerui.....	....	....	....	....	....	..	....	....	....	....	....	....	....	....	2.5	97.4
Total.....	2.56	2.09	9.83	0.86	6.99	..	0.12	25.27	16.80	3.34	12.75	1.15	13.619	0.005	0.11	4.45
	4.65		10.69		6.99		25.40		20.14		13.90		13.62		4.56	

yellowish-red, reddish-brown, and brown individuals. Strigations of dark brown upon the general ground-color also occur. Color characters, like the direction of coil, may also be different in parent and offspring. A pillar tooth usually occurs, although it varies greatly and is sometimes entirely absent. The other varieties of *P. otaheitana* display some but not all of the alternative or contrasted characters in the above categories; hence each one can be referred back to the Fautaua colony as the generalized starting-point.

B. To the eastward of Fautaua, the valleys for several miles are inhabited by *P. otaheitana amabilis* Pfeiffer, the closest relative of *P. otaheitana otaheitana*. This variety rapidly loses its dextral components in passing to Hamuta and Pirai, beyond which such individuals occur only sporadically, if at all, as far as I have observed. The color-characters are essentially the same as in the Fautaua colony, but form and size change from valley to valley. Banded examples appear very infrequently, and they are unlike the striped shells of other localities; it is amazing that heavily-banded examples of the variety named *sinistrorsa*, to be described below, are confounded with *amabilis* in nearly all of the museum collections of the world.

C. Beyond the territory occupied by *amabilis*, which in my experience ends with Ururoa Valley, begins the extensive area occupied by two sharply contrasted types. The first of these is *P. otaheitana rubescens* Reeve, a beautiful form which reaches its fullest and finest development in the far-distant valley of Oopu, at the extreme southeastern end of Tahiti nui and almost exactly opposite to Fautaua. This is the only primary variety that is *always* sinistral. It is large, yellowish or reddish in color, and devoid of strigations and revolving bands. All of its distinctive characters are exhibited by the basic variety of Fautaua Valley, but in *rubescens* they exist without an admixture of others. In range, *P. o. rubescens* extends around Tahiti nui to Apirimaue, and along the northern side of Tairapu as far as Aiurua Valley.

D. *Partula otaheitana affinis* Pease is the second primary variety whose range begins with Tuauru Valley, just beyond the region inhabited by *P. o. amabilis*. It is relatively small, predominantly dextral, brown, and strigated; *these are just the characters which P. o. rubescens lacks*. It exceeds the latter in abundance and in its territory of occupation, for it exists throughout the entire series of valleys of the eastern sector in greater numbers, as well as in nearly all of the valleys of Tairapu. The range terminates with Apirimaue Valley, where *P. o. rubescens* also stops. Well-marked subordinate varieties are to be found in certain valleys, and some of these have been earlier described as distinct species, *e. g.*, *dubia*. Banded and plain examples occur in varying proportions in different stations, and sometimes sinistral mutants are found, almost always in widely-separated localities.

E, F, G. The southern and western parts of Tahiti nui and Tairapu are inhabited by a complex series whose components agree so much *inter se* as to be set apart collectively from the other recognizable divisions of the species; nevertheless, differentiation within this series has resulted in the production of three distinguishable varieties, to which specific names have earlier been given by Pease; they are *sinistrorsa*, *sinistralis*, and *crassa*, each of which occupies a definite territory

from which the others are absent. To avoid establishing too many taxonomic grades, we will speak of this whole part of *P. otaheitana* as the "sinistral series of the south and west," and will give the status of primary varieties to its three constituent elements, under their original descriptive names. While each variety is much diversified within its subordinate area, and, indeed, within the confines of a single valley, the shells of the whole series agree in certain fundamental characters. They are typically sinistral, although dextral sports occur here and there, at times attaining considerable numbers; they are various shades of brown in color, displaying the rich yellow and red of types like *rubescens* only in certain definitely localized associations; revolving brown bands are developed in a considerable number of individuals in nearly every colony, while certain unbanded color-types recur in nearly all valleys.

*Partula otaheitana sinistrorsa* occurs in certain southwestern valleys of Taïarapu and in the southern sections of Tahiti nui as far west as Taharua Valley; *sinistralis* occupies the territory from Teohu to Vaipuarii Valleys, inclusive; finally *crassa* inhabits the western sector from Vaitupa to Taapuna Valleys.

H. The circuit of the island is completed by *P. otaheitana lignaria* Pease, which inhabits only Tipaerui Valley, adjacent to Fautaua. This variety is almost exclusively dextral, relatively small, brown and never red in color, and it is usually strigated; its casual resemblance to *P. o. affinis* disappears on closer study. Plain and banded shells constitute the two color-classes. In some parts of its valley, reversed shells of both color-divisions occur infrequently. On the whole, this variety articulates with *P. o. otaheitana* toward the east, and with hitherto undescribed relatives which exist in the neighboring valleys of the western sector.

## PARTULA OTAHEITANA OTAHEITANA VAR. NOV.

### GENERAL STATEMENT.

The members of this species that live in Fautaua Valley are first to be taken up, both because the original specimens described by Bruguière seem to have belonged to this colony and also because they form *as a group* the most generalized division of the whole *otaheitana* series, similar to the original stock from which all of the other geographical and taxonomic sections have originated. On account of its primacy in both senses, this colony will be designated as *P. otaheitana otaheitana*. Bruguière's original description, quoted in Pilsbry, is as follows:

"This species is fluviatile and was discovered during the same voyage as the preceding [Capt. Cook's] in the brooks of the island Otahiti. The shell is sinistral, oblong, oval, very thick, not more than 10 to 11 lines in length by about 6 in diameter. It is composed of 5 whorls, united exteriorly, and as much swollen as those of the *austral Bulimus*, but coiled in a direction contrary to that of most shells, that is to say, the right side of its animal is toward the left [*sic*]. The spire is conic and terminates in a pointed summit. The sutures resemble those of the preceding species [*P. faba*]. The aperture is semi-oval, oblique, rounded at the base, only a third longer than wide, and shorter by a line than half the shell. Outer lip arcuate, much reflexed and recurved to the exterior, flat and projecting outside. The inner (parietal) lip is very thin and furnished with a tooth in the middle, found only in old shells, the young having an inconspicuous callus in its place. The columella is

simple, outwardly covering an umbilicus resembling that of *Bulimus australis*. The whole shell is brown outside, or the color of roasted coffee; the lips are whitish and the cavity sooty. It is not common."

This account is erroneous in the matter of the fluviatile habit of the snail; the error may be due to the discovery of dead shells only in the bed of Fautaua stream, into which they had been washed by the rains, and to the failure of the earliest collectors to find living examples on the vegetation. This conjecture is rendered even more probable by the final comment to the effect that it is not common. In my own experience the species is at least as abundant here as in any other part of Tahiti.

In Garrett's notable monograph the description of the whole species begins with the Fautaua shells, in explicit recognition of their generalized and basic nature. Garrett says (pp. 47, 48):

"The metropolis of the typical *otaheitana* is about 2 miles up Fautaua<sup>1</sup> Valley, on the northward part of Tahiti, where it is very abundant on the trunks and foliage of trees and bushes. The above-mentioned valley being close to the principal harbor which was frequented by the earlier navigators, it is undoubtedly where Bruguière's type was obtained.

"The Fautaua shells, which are very variable in size, shape, and color, are *never ornamented by spiral bands*, and *about one-third of the specimens are sinistral*. The parietal tooth is nearly always present in the adults, and the peristome, though usually white, is frequently pinky-flesh color. The prevailing colors are straw yellow, reddish fulvous, light chestnut frequently with the spire more or less tinted with reddish and often with longitudinal strigations. The spire is more or less produced, and the aperture varies some in size and shape. [*Italics mine.*]

"The shape of the shell varies from abbreviate-ovate to elongate-ovate, as the following measurements will show:

"Length 21, diameter 10 mm.	Dextral specimen.
Length 16, diameter 10 mm.	Dextral specimen.
Length 20, diameter 10 mm.	Sinistral specimen.
Length 16, diameter 9 mm.	Sinistral specimen."

The specimens of the present research comprise several beautifully banded shells which seem to be newcomers in this valley since Garrett's time. Again, in my own series 40 per cent are dextral, not two-thirds as Garrett states for the earlier period. The significance of this discrepancy will be discussed beyond, when Mayer's figures will also be taken into account; but even at the outset it appears that a distinct change in the colony as a whole has been brought about in recent decades.

#### FAUTAU VALLEY AND THE AREA OF COLLECTION.

The valley of Fautaua is justly famed on account of its wonderful beauty. It is one of the largest in all Tahiti, being equaled by few and exceeded greatly by Papenoo only because the latter forms the major outlet from the ancient central crater of the whole island massif (*cf.* plates 9, 10, and 11). At its mouth it is fully three-quarters of a mile in width, but at a radial distance of a mile or so from the shore its sides draw together and rise more abruptly. Naturally the vegetation

<sup>1</sup>In Garrett's monograph, this name is consistently misspelled "Fautana,"—an error that should not be perpetuated even in quotation.

becomes more succulent, and the guava trees of the drier coastward parts diminish in numbers. At about 2 miles inland the valley divides, and above this point of division stands the sharp-pointed Pic de Français, a characteristic example of the valley borders in this and other interior regions (plate 7*b*). Along the western branch the valley narrows and deepens vertically until it is a gorge of 700 to 800 feet in depth, with abrupt walls that become sheer at the head of a canyon where the beautiful Falls of Fautaua pour from the inland extension of the valley. Above these falls the gradient becomes easier and finally the head-streams may be traced to their beginnings at the foot of "Venus's Diadem," a pinnacled rock that presents many of the features of the spine of Mont Pelée in Martinique.

In my experience the *Partulæ* do not extend in any great numbers above the falls. They are most abundant on the lower levels about  $3\frac{1}{2}$  to 4 miles inward from the shore. They occur on caladium and wild plantain with especial frequency; at times as many as 8 or 9 snails may be found on a single gigantic leaf of the former, snails that are dextral and reversed, light and dark in color, along with some individuals of *P. hyalina*. To all intents and purposes the area inhabited by *P. otaheitana otaheitana* is compact, continuous, and well-populated. The series of different years were taken from the *same general locality*, and probably not more than 2 miles intervened between the most coastward and the most inland specimens. The importance of this fact for future discussion is self-evident.

#### DESCRIPTION OF THE FAUTAU SHELLS.

The material in my own hands was secured in 1906, 1907, and 1908. In the first and second of these years many trips were made into Fautaua in order to study the conditions of temperature and humidity that affect the *Partulæ*, and hence the collections of those years are most satisfactory. The series of 1908 was obtained for me by Chief Mote. In that year, as well as in 1909, the greater part of the time of sojourn in the islands was employed in exploring other members of the Society Group, as well as Samoa, Tonga, etc. After discarding a few of the snails for one reason or another, such as mutilated condition, there remain 955 adults and 396 adolescent individuals, while the former have furnished 1,182 young and eggs, of which over 500 were sufficiently advanced to give data relating to the heredity of color and of the coil of the shell.

The adult shells of this colony present features that for convenience may be termed unit-characters, some of which are strictly alternative, while others exhibit fluctuations so as to merge into one another. These fall into three groups, as they are displayed in (1) the coil of the shell, (2) the color, and (3) the dimensions of the shell and of its parts.

(1) In the coil the shells are either dextral or sinistral; of necessity no intermediate condition could exist. It will appear hereafter that the two types do not breed absolutely true, as Mayer was the first to point out, for sinistral young are produced by dextral adults and *vice versa*. But it is noteworthy (again as first established by Mayer) that the young contained in an adult at any one time are either *all dextral* or *all sinistral*, and may thus differ collectively from their parent.

(2) The color characters are naturally more complex. First of all is the division into plain and banded types; the bands are revolving stripes, always of a darker color entirely different from the strigations that run longitudinally, as the systematists describe them (plate 25, figs. 38 and 39). Actually, on the basis of internal structure, the bands should be called longitudinal and the strigations transverse, but the terminology of the taxonomists who have dealt primarily with the shell will be employed nevertheless.

Of the plain shells, four classes are distinguishable on the basis of the general ground-color, which may be yellowish (Class I, plate 25, figs. 1 to 7), fulvous yellow (Class II, plate 25, figs. 8 to 18), reddish brown (Class III, plate 25, figs. 19 to 28), or brownish, with or without some addition of red (Class IV, plate 25, figs. 29 to 37). These classes merge into one another through intermediates, but the majority of the shells group themselves about the four typical colors as given. Strigations of the transverse order may or may not be present. They occur more abundantly on the shells with darker ground-colors.

The apex of the spire may be of the same hue as the rest of the shell, or it may be deeply stained to a purplish red. The deeply colored apex may occur on a light shell or on one with darker ground-colors.

The lip and its adjacent lining may be pure white, as in the great majority of cases, or it may be uniformly suffused with light purple, or purplish brown.

In dimensions the shells vary so as to present a curve of error in all of the seven characters defined in the cases of *hyalina*, *clara*, and *nodosa*. It is not possible to make a qualitative or alternative classification on the basis of these characters.

Finally, the pillar tooth may be absent, present as a diminutive process, present and well-marked, large or very large.

In summary, then, the more or less independent characters of the *Fautaua* shells may be tabulated as follows:

*Coil:* Sinistral : Dextral.

*Color:*

Basis ..... I. Yellowish : II. Yellow-fulvous : III. Reddish : IV. Brown.

Bands ..... Present : absent (= "plain").

Strigations ..... Present : Absent.

Apex ..... Unmodified : Tinged.

Lip ..... White : Tinged.

*Dimensions:*

Whole shell ..... Variable continuously.

Aperture ..... Variable continuously.

Proportions ..... Variable continuously.

Tooth ..... Absent : Trace : Average : Large : Very large.

A given individual possesses a group or combination of characters, each of which is *one* of the two or more possible qualities under a given head. Thus one shell is dextral, unbanded, reddish (Class III), strigated, with tinted apex, white lip, and above the average in the dimensions of the whole shell, below the average in aperture dimensions, and devoid of a tooth; another presents some of the above, together with alternative or at any rate distinctively different qualities in other respects. Hence no single shell and no small number of shells could be justly regarded as a "type" or as "typical," for we must take into account all of the varied



combinations of characters or fluctuations of these in order to define the complex of heritable qualities possessed by the colony as a whole.

We may now pass to the consideration of the inter-relationships of the different component classes of the Fautaua colony, in sufficient detail to ascertain: (1) whether the two classes of sinistral and dextral shells are materially different; (2a) whether the banded individuals constitute an independent stock or are sporadic products of the plain group; and (2b) whether the four principal color-classes are statistically different.

#### COMPARISON OF SINISTRAL AND DEXTRAL SHELLS.

##### NUMERICAL RELATIONS.

The numerical relations of the dextral and reversed individuals in my collections are not the same in successive years. For obvious reasons the series of 1906 and 1907 are more important than the last lot, which comprised a larger proportion of adolescent snails of nearly full growth. The detailed figures are given in table 57,

TABLE 57.—*Partula otaheitana otaheitana*, Fautaua Valley. Numerical relations of the form-classes.

	Adults.		Adolescents.		Adults and adolescents.		Embryonic young.	
	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.
1908, sin.....	64	50.7	27	54.0	91	51.7	51	51.0
dex.....	62	49.2	23	46.0	85	48.2	49	49.0
1907, sin.....	230	56.6	92	52.2	322	55.1	117	47.9
dex.....	176	43.3	84	47.7	260	44.8	127	52.0
1906, sin.....	229	54.5	85	50.0	314	53.2	85	50.0
dex.....	191	45.4	85	50.0	276	46.7	85	50.0
1906-1908, sin.....	523	54.9	204	51.5	727	53.9	253	49.2
dex.....	429	45.0	192	48.4	621	46.0	261	50.7
1899, Mayer, sin.....	...	54	...	....	...	....	64	55.6
dex.....	...	46	...	....	...	....	51	44.3
1870-1885, Garrett, sin.....	...	33±	...	....	...	....	...	....
dex.....	...	66±	...	....	...	....	...	....

together with the data of Garrett and Mayer; they indicate that the relative number of sinistral snails is diminishing after a long period of increase. Specifically, the original statement of Garrett is that "about one-third of the shells are sinistral"; the period of observation can safely be given as between 1870 and 1885, although Garrett's first sojourn in the island was from 1860 to 1863. Mayer found in 1899 that the reversed shells amounted to 54 per cent in an *otaheitana* collection of 138 individuals from this valley, while the young dissected out of the adults of both form-classes showed a slightly higher percentage of the same coil, 64 per cent; hence a great relative increase of sinistral individuals must have taken place subsequent to Garrett's studies. In 1906 the adults were in about the same condition as in Mayer's time, but both the adolescents and the embryonic young of this coil have dropped to 50 per cent. The effect of this reduction would not be manifested in the adult population until at least a year had elapsed, so that the 1907 shells would be less significant than those of 1908. The full-grown snails of this last year

show only 50.7 per cent sinistral, although their young exhibit a slight increase over this figure.

To sum up, it would seem that (a) the relative numbers of dextral and sinistral shells vary from time to time; (b) that a marked increase in the sinistral type occurred during the last quarter of the nineteenth century; and (c) that subsequently a slight relative decrease of the same type has supervened. Obviously a study of the facts after an interval of 15 to 25 years would be of the greatest interest and value.

#### COLOR AND COLORATION.

While the comparison of the several color-classes is to be made at a later juncture, it is important at this point to note whether the shells of one direction of coil comprise a larger proportion of the individuals of any one class. The figures of table 60 give the following results: the only banded shells—3 out of 955—were sinistral; shells with the reddish coloration constitute nearly 50 per cent of both the direct and the reversed form-classes; the Class I shells are next in abundance, almost uniformly in the several series, and they are followed by Class II and then by Class IV. The above facts show that no wide differences in color composition distinguish the sinistral and dextral groups from one another—that is to say, no real differentiation on the basis of color accompanies the difference in the direction of the spiral.

The hereditary relations between the two form-classes are sufficiently important to demand separate treatment at a later point. Here we may restate the essential fact that the young of either kind are sometimes of the contrasted direction of coil.

#### DIMENSIONS.

The next question of importance deals with the existence of real differences between the sinistral and dextral shells in dimensional respects that would be brought to light only by employing statistical methods; the two classes can not be absolutely distinct, like two entirely different species, such as the sinistral *P. mooreana* and the dextral *P. suturalis* of Vaianae Valley in Moorea, for the reason stated in the previous paragraph. Yet the immediate question is one of prospective interest, if nothing more, because other valleys of Tahiti contain varieties of *P. otaheitana* which exist in both the direct and the reversed states.

The most striking results of comparing the two classes on the basis of dimensional statistics (table 58) is the fact that the sinistral shells are certainly shorter in total length, and certainly stouter in shell proportions; the differences are respectively 5 and 6 times their probable errors. The shells of the former group are shorter also in aperture length with probability only, wider with certainty, and the aperture is certainly longer with reference to the total length of the shell. In brief, the sinistral shells are more tightly coiled than those of the contrasted group, which on the whole are substantially the same in color and markings, and to which they sometimes contribute representatives from among their offspring.

The curves of variation of the two groups of shells are given in table 59; they show graphically the degrees of resemblance and difference in all seven of the standard characters.

TABLE 59. *Partula otaheitanus otaheitanus*, Fautaua Valley. Frequency polygons of the characters of sinistral and dextral shells. (Sinistral, full lines; dextral, interrupted lines.)





TABLE 59. *Partula otaheitana otaheitana*, Fautaua Valley. Frequency polygons of the characters of sinistral and dextral shells. (Sinistral, full lines; dextral, interrupted lines.)

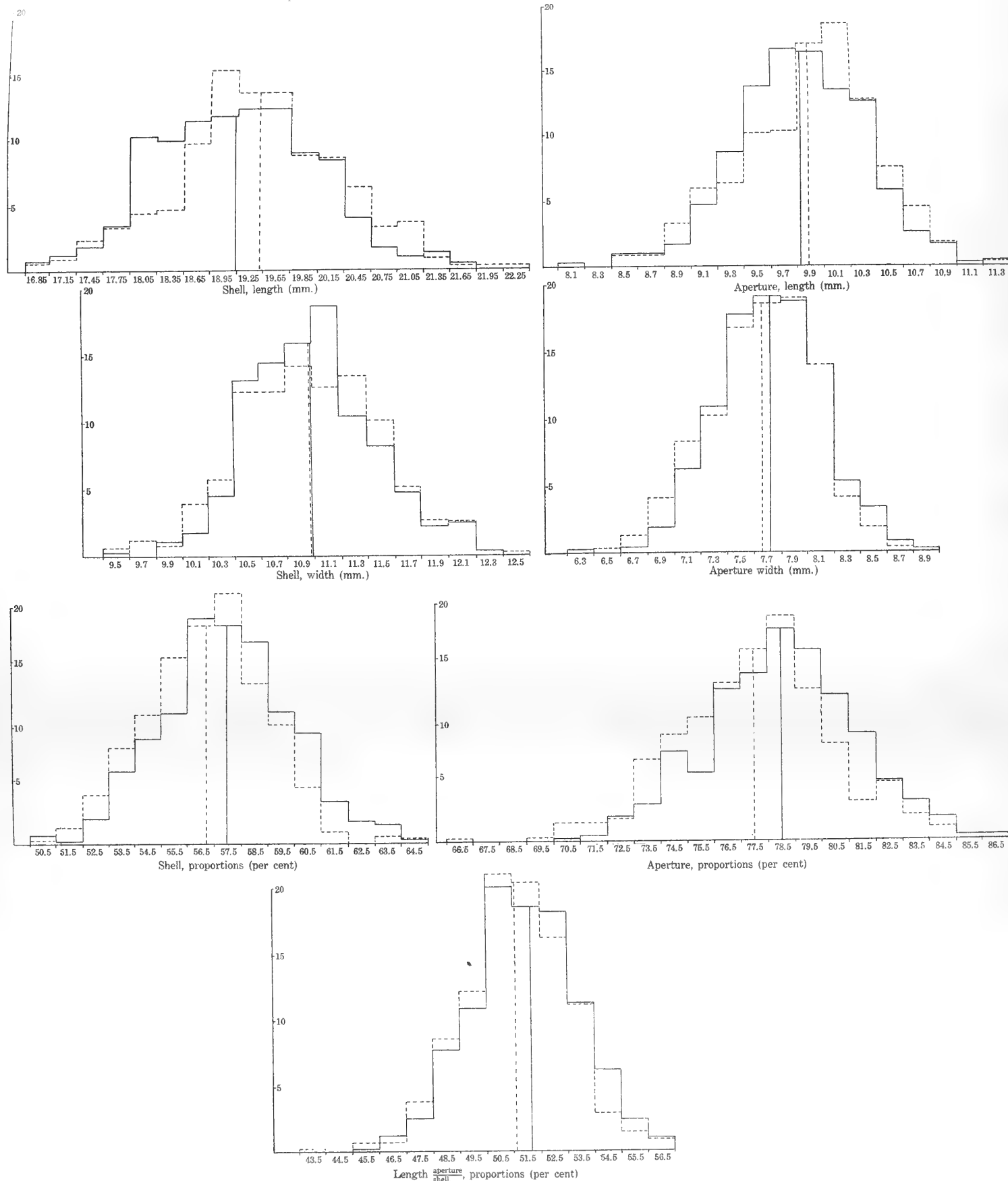




TABLE 58.—*Partula otaheitana otaheitana*, *Fautaua Valley*. Comparison of unbanded sinistral and dextral shells.

	Sinistral [506].		Dextral [421].		Differences.	
	Mean value.	Standard deviation.	Mean value.	Standard deviation.	Mean value.	Standard deviation.
Shell, length, mm. ....	19.0958 ± .0268	0.8943 ± .0190	19.3184 ± .0304	0.9263 ± .0215	-0.2226 ± .0405	-0.0320 ± .0287
width, mm. ....	10.9870 ± .0140	.4664 ± .0099	10.9736 ± .0172	.5219 ± .0122	+ .0034 ± .0221	- .0545 ± .0157
proportions, p. ct. ....	57.4269 ± .0794	2.6485 ± .0562	56.7447 ± .0745	2.2660 ± .0527	+ .6822 ± .1089	+ .3825 ± .0770
Aperture, length, mm. ....	9.8312 ± .0143	.4768 ± .0101	9.8853 ± .0163	.4969 ± .0115	- .0541 ± .0216	- .0201 ± .0153
width, mm. ....	7.7245 ± .0116	.3856 ± .0082	7.6667 ± .0130	.3943 ± .0092	+ .0578 ± .0174	- .0087 ± .0123
proportions, p. ct. ....	78.4862 ± .0819	2.7326 ± .0579	77.4976 ± .0937	2.8505 ± .0663	+ .9886 ± .1244	- .1179 ± .0880
Length aperture ÷ length shell, proportions, p. ct. ....	51.4130 ± .0593	1.9772 ± .0419	51.1176 ± .0644	1.9595 ± .0455	+ .2954 ± .0875	+ .0177 ± .0618

## COMPARISON OF THE COLOR-CLASSES.

The object of this comparison is to ascertain whether differentiation in dimensional respects accompanies that which is expressed in general ground-color or in the matter of the banded coloration. The later study of the Pirai snails will articulate directly and significantly with this comparison.

The absolute and proportionate numbers referable to the several color-classes are given in table 60, already noted in an earlier connection. There is nothing here that is indicative of a definite and consistent hereditary predisposition in any class in favor of one or the other mode of coil.

TABLE 60.—*Partula otaheitana otaheitana*, *Fautaua Valley*. Numerical relations of the color-classes.

Series.	No.	Number plain.				Number banded.	Per cent plain.				Per cent banded.
		Class I.	Class II.	Class III.	Class IV.		Class I.	Class II.	Class III.	Class IV.	
Sinistral, 1906. ....	229	47	34	111	37	..	20.5	14.8	48.4	16.1	...
1907. ....	230	46	41	116	27	..	20.0	17.8	50.4	11.7	...
1908. ....	67	11	12	29	12	3	16.4	17.9	43.3	17.9	4.4
Dextral, 1906. ....	191	36	40	87	28	..	18.8	20.9	45.5	14.6	...
1907. ....	176	29	31	95	21	..	16.5	17.6	53.9	11.9	...
1908. ....	62	14	6	32	10	..	22.6	9.6	51.6	16.1	...
Sinistral, all. ....	526	104	87	256	76	3	19.8	16.5	48.7	14.4	0.5
Dextral, all. ....	429	79	77	214	59	..	18.4	17.9	49.9	13.7	...
Total. ....	955	183	164	470	135	3	19.1	17.1	49.2	14.1	0.3

We come now to the statistics relating to the seven standard characters of the shell, together with the eighth quality of tooth development (tables 61 and 62). The first general result is that the three-banded and sinistral shells are statistically different from the plain or unbanded examples. Specifically the former, as compared with the contrasted sinistral group, are as follows:

Shell, length in millimeters. ....	+0.7542 ± .3449
width in millimeters. ....	+0.3130 ± .1109
proportions (per cent). ....	-0.9269 ± .6000
Aperture, length in millimeters. ....	+0.1355 ± .1841
width in millimeters. ....	-0.0912 ± .0385
proportions (per cent). ....	-1.9862 ± 1.1044
Length aperture ÷ length shell, proportions, per cent. ....	-0.9130 ± .3235
Tooth (index). ....	+0.2879 ± .0664

TABLE 61.—*Partula otaheitana otaheitana*, Fautau Valley. Analysis of the color-classes.

MEAN VALUE.								
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.	
		mm.	mm.	p. ct.	mm.	mm.	p. ct.	p. ct.
Sin., plain, I.	101	19.0331 ± .0555	10.9237 ± .0295	57.2326 ± .1457	9.8446 ± .0324	7.7118 ± .0240	78.0445 ± .1828	51.7970 ± .1310
II.	84	19.2107 ± .0718	10.9571 ± .0352	56.9285 ± .1837	9.8810 ± .0353	7.7142 ± .0278	78.1071 ± .1917	51.3452 ± .1455
III.	249	19.1198 ± .0379	11.0478 ± .0205	57.6927 ± .1062	9.8165 ± .0213	7.7530 ± .0173	78.9498 ± .1132	51.2068 ± .0846
IV.	72	18.9667 ± .0706	10.9000 ± .0325	57.3611 ± .1774	9.8056 ± .0295	7.6556 ± .0282	77.9444 ± .2309	51.6666 ± .1504
Sin., banded . .	3	19.8500 ± .3439	11.3000 ± .1101	56.5000 ± .5948	9.9667 ± .1836	7.6333 ± .0367	76.5000 ± 1.1014	50.5000 ± .3180
All, plain. . . . .	506	19.0958 ± .0268	10.9870 ± .0140	57.4269 ± .0794	9.8312 ± .0143	7.7245 ± .0116	78.4862 ± .0819	51.4130 ± .0593
All. . . . .	509	19.1003 ± .0268	10.9888 ± .0142	57.4373 ± .0719	9.8321 ± .0142	7.7239 ± .0115	78.4744 ± .0818	51.4076 ± .0590
Dex., plain, I.	78	19.3307 ± .0722	11.0692 ± .0425	57.1923 ± .1529	9.9231 ± .0401	7.7231 ± .0305	77.7948 ± .2025	51.2692 ± .1497
II.	76	19.4339 ± .0698	11.0210 ± .0371	56.8026 ± .1712	9.9684 ± .0346	7.7605 ± .0311	77.7899 ± .2334	51.2894 ± .1394
III.	208	19.2875 ± .0423	10.9173 ± .0235	56.5009 ± .1118	9.8702 ± .0233	7.6279 ± .0174	77.2260 ± .1391	51.1298 ± .0932
IV.	59	19.3008 ± .0876	10.9847 ± .0497	56.9067 ± .1842	9.7814 ± .0431	7.6085 ± .0367	77.7103 ± .2005	50.6525 ± .1707
All. . . . .	421	19.3184 ± .0304	10.9736 ± .0172	56.7447 ± .0745	9.8853 ± .0163	7.6667 ± .0130	77.4976 ± .0937	51.1176 ± .0644
STANDARD DEVIATION.								
Sin., plain, I.	101	0.8263 ± .0392	0.4389 ± .0208	2.1706 ± .1030	0.4826 ± .0229	0.3580 ± .0169	2.7233 ± .1292	1.9526 ± .0926
II.	84	.9762 ± .0507	.4786 ± .0249	2.4969 ± .1299	.4806 ± .0250	.3777 ± .0196	2.6050 ± .1355	1.9790 ± .1029
III.	249	.8871 ± .0268	.4799 ± .0145	2.4859 ± .0751	.4984 ± .0151	.4041 ± .0122	2.6487 ± .0800	1.9789 ± .0598
IV.	72	.8887 ± .0499	.4096 ± .0230	2.2323 ± .1254	.3711 ± .0208	.3547 ± .0199	2.9054 ± .1633	1.8929 ± .1063
Sin., banded . .	3	.8831 ± .2432	.2828 ± .0779	2.1602 ± .8412	.4714 ± .1298	.0942 ± .0259	2.8284 ± .7788	0.8165 ± .2249
Sin., all, plain.	506	.8943 ± .0190	.4664 ± .0099	2.6485 ± .0562	.4768 ± .0101	.3856 ± .0082	2.7326 ± .0579	1.9772 ± .0419
Sin., all. . . . .	509	.8961 ± .0189	.4768 ± .0100	2.4049 ± .0508	.4769 ± .0100	.3845 ± .0081	2.7369 ± .0579	1.9737 ± .0417
Dex., plain, I.	78	.9452 ± .0510	.5575 ± .0300	2.0019 ± .1081	.5252 ± .0283	.3999 ± .0215	2.6511 ± .1432	1.9606 ± .1058
II.	76	.9019 ± .0493	.4797 ± .0262	2.2125 ± .1210	.4478 ± .0244	.4026 ± .0220	3.0166 ± .1650	1.8014 ± .0986
III.	208	.9040 ± .0299	.5020 ± .0166	2.3898 ± .0790	.4981 ± .0165	.3726 ± .0123	2.9753 ± .0983	1.9982 ± .0659
IV.	59	.9991 ± .0619	.5671 ± .0351	2.1002 ± .1302	.4914 ± .0305	.4188 ± .0259	2.2862 ± .1418	1.9468 ± .1207
Dex., all, plain.	421	.9263 ± .0215	.5219 ± .0122	2.2660 ± .0527	.4969 ± .0115	.3943 ± .0092	2.8505 ± .0663	1.9595 ± .0455

TABLE 62.—*Partula otaheitana otaheitana*, Fautau Valley. Color-classes: Tooth.

	No.	Distribution.					Constants.	
		None. (1)	Trace. (2)	Tooth. (3)	Large. (4)	Very large. (5)	Mean.	Standard deviation.
Sinistral, plain, I. . . . .	104	9	23	57	14	1	2.7597 ± .0546	0.8262 ± .0386
II. . . . .	87	10	15	50	11	1	2.7472 ± .0622	.8606 ± .0440
III. . . . .	254	41	44	128	36	5	2.6851 ± .0410	.9695 ± .0290
IV. . . . .	76	10	12	46	7	1	2.6974 ± .0664	.8586 ± .0469
Sinistral, bands. . . . .	3	0	0	3	0	0	3.0000 ± .0000	.0000 ± .0000
all, plain. . . . .	521	70	94	281	68	8	2.7121 ± .0269	.9093 ± .0190
Sinistral, all. . . . .	524	70	94	284	68	8	2.7138 ± .0267	.9069 ± .0189
Dextral, plain, I. . . . .	79	12	9	49	9	0	2.6962 ± .0654	.8620 ± .0462
II. . . . .	77	8	8	45	13	3	2.9351 ± .0704	.9165 ± .0498
III. . . . .	214	28	37	124	22	3	2.6963 ± .0411	.8734 ± .0291
IV. . . . .	59	6	10	31	11	1	2.8475 ± .0788	.8985 ± .0557
Dextral, all. . . . .	429	54	64	249	55	7	2.7600 ± .0289	.8880 ± .0204



The differences in the case of the three shell characters are significant with high probability; the divergence in width and proportions of the aperture are also probably significant, and the proportion of aperture length to shell length is also different with practical certainty; finally the tooth reaches a higher average degree of development.

Yet the relationship of the banded to the plain shells is indubitable. The single young snail taken from a banded adult is plain (*q. v.*), and furthermore, in all cases the measurements of the banded shells fall well within the range of variability of the same character of the plain shells. Therefore, we can not regard as stragglers the striped individuals which have come from the neighboring valley of Hamuta or from any other place, where similarly colored shells may be found more frequently; it seems more justifiable to consider them as mutants produced only sporadically by the general unbanded stock. According to the latter interpretation it would naturally follow that the dimensions of such sports would follow those of their parents, and only if such parents occupied widely separated positions along the range of a given character, and if, furthermore, their mutant offspring were actually numerous, would the average value of this character be approximately the same in the small group of mutants as in the class of unbanded snails taken as a whole.

The second general point established by the figures of table 61 is that the darkest sinistral snails tend to be smaller than their similarly coiled relatives, but they do not differ to a significant degree. Cross-breeding between and among the members of all four classes in each coil prevails to a great extent; wherefore no distinctive dimensional peculiarities of any color-class would be expected.

#### FECUNDITY.

The statistics of fecundity for the Fautaua colony are given in table 63. Here it is permissible to combine the data for the sinistral and dextral individuals. Conceivably the two kinds might differ in their rates of multiplication, and if so, the difference would be a potent factor of change in the colony as a whole as regards the proportionate numbers of the two kinds of shells; but the facts indicate that there is no real difference in the rate of reproduction.

TABLE 63.—*Partula otaheitana otaheitana*, Fautaua Valley. Statistics of fecundity.

Group.	Records.	No. of gravid.	Per cent gravid.	Eggs.	Young.	Total contents.	Average for gravid.	Average for all.
Sinistral, 1906, Feb. ....	185	91	49.19	62	96	158	1.73	0.85
1907, June (?) .....	169	138	81.66	195	143	338	2.45	2.00
1908, Sept. ....	67	59	88.06	103	50	153	2.59	2.28
Dextral, 1906, Feb. ....	160	75	46.87	57	74	131	1.74	0.82
1907, June (?) .....	128	106	82.81	165	101	266	2.51	2.09
1908, Sept. ....	62	57	91.93	86	50	136	2.38	2.19
Sinistral, all years .....	421	288	68.41	360	289	649	2.25	1.54
Dextral, all years .....	350	238	68.00	308	225	533	2.24	1.52
Sinistral and dextral, 1906 .....	345	166	48.11	119	170	289	1.68	0.83
1907 .....	297	244	82.15	360	244	604	2.47	2.03
1908 .....	129	116	89.92	189	100	289	2.49	2.24
All, sinistral and dextral .....	771	526	68.22	668	514	1,182	2.24	1.53

It will be recalled that the series of 1906 was taken in February and March, toward the end of the rainy season, while that of 1907 was secured in June, and the smaller lot of 1908 in September. Taking these series as typical of the whole population, a distinct rise in the rate of productivity occurs with the progress of time from the early months to June and to September. Such facts indicate that the breeding-season in this valley begins with the heavier rains, when the greater amount of moisture stimulates the snails to increased activity in every functional respect.

## HEREDITY.

We come at last to the highly interesting statistics of heredity, to which passing reference has been made at one or another point in the foregoing description. The figures are given in full and in summary in table 64. Naturally, it is difficult

TABLE 64.—*Partula otaheitana otaheitana*, Fautaua Valley.

FULL STATISTICS OF HEREDITY.									
Form and color-classes, adults.	Color-class, sinistral, young.				Color-class, dextral, young.				Total.
	I.	II.	III.	IV.	I.	II.	III.	IV.	
Sinistral, plain, I.....	24	5	13	1	9	6	1	1	60
II.....	19	9	8	..	3	7	8	..	54
III.....	27	15	44	8	10	6	23	3	136
IV.....	5	5	10	10	3	..	4	1	38
Sinistral, bands.....	..	1	..	..	..	..	..	..	1
Sinistral, all.....	75	35	75	19	25	19	36	5	289
	204				85				
Dextral, plain, I.....	5	1	3	..	17	2	7	3	38
II.....	1	..	1	2	13	5	7	4	33
III.....	3	4	7	11	22	22	17	29	115
IV.....	4	1	..	6	4	..	12	12	39
Dextral, all.....	13	6	11	19	56	29	43	48	225
	49				176				
Total.....	88	41	86	38	81	48	79	53	514
	253				261				

HEREDITY OF COLOR-CHARACTERS.						HEREDITY OF COIL.			
	Young, plain.						Young.		
	I.	II.	III.	IV.	Total.		Sinistral.	Dextral.	Total.
Adults:						Adults:			
Plain, I....	55	14	24	5	98	Sinistral....	204	85	289
II....	36	21	24	6	87				[56.22 p. ct.]
III....	62	47	91	51	251	Dextral....	49	176	225
IV....	16	6	26	29	77				[43.77 p. ct.]
Bands.....	..	1	..	..	1	Total....	253	261	514
Total.....	169	89	165	91	514		[49.22 p. ct.]	[50.77 p. ct.]	

to determine with exactness the precise color-class to which an embryonic snail should be assigned, on account of the relative thinness of the newly-formed shell; hence too much stress should not be laid upon discrepancies between the proportionate numbers of young and adults in the several classes.

The salient points established by the detailed observations are as follows:

(1) The dextral individuals that bear young number 43.7 per cent of the three annual series taken together, while dextral young snails constitute 50.7 per cent of the whole number. We are justified in concluding, then, that the dextral character is now in the ascendant, after a long period of sinistral dominance.

(2) The banded and plain classes are not physiologically separate. The single gravid snail with a banded shell bore one plain young of Class II; of the offspring taken from the plain adults not a single specimen showed distinct bands, although such might have occurred with the peculiar coloration so faint as to escape detection. The one plain snail from the banded parent is best interpreted, I believe, as a reversion to the simple type, perhaps in the Mendelian sense of a dominant-recessive, where the mutant character would be the recessive of the couple. Obviously more data are required before this interpretation should be adopted, even provisionally.

(3) The color-classes are not physiologically distinct. With the exception of Class I snails, the characteristic color breeds true in less than 50 per cent of the cases. The situation is too complex to permit an analysis in Mendelian terms, even though the material is abundant. To settle the question as to a Mendelian course of heredity, experiments are absolutely essential.

#### SUMMARY AND CONCLUSION.

The snails of the Fautaua colony form an extremely complex stock, whose members differ in characters of many kinds, viz, color and coloration, direction of spirality, dimensions, and proportions. It will appear that this complex stock stands in a parental relation to the diverse colonies of other valleys and regions; in any one of the latter the shells exhibit one combination or another of the so-called unit characters displayed by the Fautaua group as a whole. For example, they may be exclusively sinistral, yellow or red, but never brown, universally devoid of a tooth, and large, as in *P. otaheitana rubescens*; or they may be always dextral, brown, strigated, with a well-developed tooth, like some of the isolated groups of *P. otaheitana affinis*. In no valley, however, are any distinctive characters *added* to the complex of the Fautaua colony.

The alternative view that *P. o. otaheitana* is a synthesis of diverse stocks which originated elsewhere and whose emigrants have met in Fautaua Valley presents itself as a possibility, but it is not supported by the facts which will appear as we proceed. A significant detail is that migration from one valley to another is all but impossible in the northwestern region where Fautaua lies. Again, characteristics such as the large size, clear red and yellow ground-colors, and invariable sinistrality displayed by *rubescens* of Oopu Valley in their purity could scarcely have been contributed by such a far-distant community to the colonial qualities of the Fautaua group. All points considered, it seems more logical to regard *P. otaheitana ota-*

*heitana* as the relatively unchanged descendant of an old stock of great intrinsic complexity, formerly widespread over Tahiti, and one whose descendants in other valleys have dropped out one or more of the original qualities which have been retained by some of the varying members of the Fautaua association.

## PARTULA OTAHEITANA AMABILIS Pfeiffer.

### GENERAL STATEMENT.

Beginning with the small valley of Hamuta, the immediate eastward neighbor of Fautaua, the valleys as far as Tuauru are inhabited by representatives of *Partula otaheitana* that are sufficiently distinctive to be grouped together as a primary variety; this is called *amabilis* because certain characteristic shells were described by Pfeiffer as a separate species under that name. The variety ranges through Hamuta, Pirai, Pohaitara, and Ururoa valleys, giving place beyond to the invariably sinistral *rubescens* and the predominantly dextral *affinis*.

Pfeiffer's original description of *amabilis* is as follows:

"Shell sinistral, subperforate, ovate-turrite, rather solid, striatulate, glossy, citrine, the acute apex reddish, suture white-edged. Whorls five, the upper flat, the rest convex, the last shorter than the spire. Columella nearly simple, slightly plicate. Aperture oblong-semi-oval. Peristome somewhat thickened, white, expanded and reflexed, the columella margin wide, flat, spreading. Length 23; diam. 11; aperture inside  $9\frac{1}{2}$  to 10 mm. long, 5 wide. A variety is somewhat smaller, ornamented with wide blackish-chestnut bands, the peristome livid brown."

Two items of the above account are amazingly incorrect. *P. o. amabilis* is not as long as 23 mm. in a single shell out of more than 3,000 in my collections. Only a few examples of *P. o. rubescens*, at the height of its development in Oopu Valley, far to the southeast, exceed 23 mm.; an equally small number of the *P. o. sinistrorsa* series, again far to the southeast, are as long as 23 mm. I suspect that the figure given by Pfeiffer is incorrect to the extent of 5 mm., 23 being read for 18 on the scale. In the second place, no specimens of *amabilis* occur with "wide blackish-chestnut bands"; such shells are members of the *sinistrorsa* series. Pfeiffer's error in this respect is perpetuated in practically all the large conchological collections of the world, excepting only those which were made and labeled by Garrett, who was well acquainted with *amabilis* and other varieties from his own experience.

Garrett's monograph gives the following description of the distribution of *amabilis* (p. 48):

"To the eastward between Fautaua and Papenoo Valley, a distance of about eight miles, there are three valleys, all inhabited by Pfeiffer's *amabilis*, a sinistral form that has not a single feature to distinguish it from some of the larger turreted Fautaua shells. In the first valley [Hamuta], Pfeiffer's species, though not abundant, were very fine specimens. The next valley, known as Pirai (the metropolis of the small dextral *P. filosa*, which occupies the lower part of the valley) is, in the upper part, which trends toward the headquarters of *otaheitana*, inhabited by the sinistral *amabilis*. A few immature examples were found which were banded like *Lignaria*. The only dextral Partulæ taken in the two

valleys were *filosa*, *attenuata*, and *hyalina*. \* \* \* In the next valley, called Haona, I found the dextral *affinis* abundant, and took a few of *amabilis*. \* \* \* Both Dr. Pfeiffer and Dr. Reeve described the latter species from specimens in the Cumingian collection, and both quote Anaa, a low coral island, as its habitat. Having resided about five months on that island, and searched all parts for shells, I did not find a single *Partula* there, or on any low coral island. Though neither Pfeiffer nor Reeve allude to a parietal tooth, it is frequently present."

Everything in this statement is of fundamental importance. Apparently Garrett passed by the smaller gullies in the sector between Fautaua and Papenoo, such as Pohaitara and Ururoa, from the upper parts of which I secured snails, although the lower parts are barren of these animals. Haona Valley could not be identified by that name, either on the basis of the territorial records or through consultation with the native chiefs. By Haona, Garrett possibly meant Ahonu, of which the last letter is easily mistaken for an *a*, while a transposition of the first two letters of a name is by no means uncommon; yet the snails of Ahonu scarcely agree with Garrett's description, even allowing for drastic changes since his time.

When Garrett says that the only dextral specimens in the two valleys—Hamuta and Pirai—were *filosa*, *attenuata*, and *hyalina*, it is possible that he was guilty of a *lapsus calami*, thinking only of Pirai, where such is the case; but either he erred regarding the population of Hamuta or an astonishing change has taken place since his day. In my own collections and in Mayer's the dextral individuals of *amabilis* number fully one-third of the whole representative population.

One further general point is that Garrett correctly notes the presence of narrowly-banded snails somewhat similar to *lignaria*, a primary variety of Tipaerui Valley, to the west of Fautaua. He speaks of immature examples only, while Mayer and I have secured adults and embryonic young as well. These individuals are not really related to *lignaria*, as the future account will show; the essential point is that they are entirely distinct from *sinistrorsa*, which Pfeiffer confused with *amabilis*.

The census table for the whole island (table 9) and the more specific table 56, referring to *P. otaheitana*, give the absolute and relative numbers of *amabilis* in the valleys of its range. We may now pass to the detailed description of this primary variety as it exists in varying forms throughout its territory.

#### HAMUTA VALLEY.

This valley is close to Fautaua, from which it is separated by only one flat-topped ridge (plates 5*a*, 9, 10, and 11). It bends sharply to the east and then to the west, trending toward the eastern branch of Fautaua, and grades rapidly upwards as it is followed inland. Finally it is lost high up on the divide between the middle portions of Pirai and Fautaua Valleys. Drier and less wooded ridges seem to be effectual barriers to the snails inhabiting the upper portions of Hamuta and its neighbors, although the possibility of actual migrations from one to another during long-continued periods of rain can not be absolutely eliminated.

The collections of the present research were obtained from substantially the same part of this valley in 1906, 1907, and 1909; as in Fautaua, therefore, the

specimens of the several years came from one habitable area. In 1906, however, owing to the severe cyclonic disturbance of February, the interior was very difficult of access on account of the fallen trees and tangled vegetation. Only the extreme outer fringe of the inhabited area was reached, which circumstance accounts in part for the small numbers obtained in the first year. As in Garrett's time, *amabilis* is by no means abundant in this valley, a second reason for the paucity of material.

The shells fall into the same color groups that were established in the case of the Fautau colony, in each of the two modes of coil (plate 25, figs. 44 to 65). Virtually all of the combinations of characters specified by *P. o. otaheitana* are repeated in *amabilis* of Hamuta, although even a cursory examination shows that the general dimensions are different in degree, while furthermore the proportionate numbers assignable to the various subdivisions by no means agree with those in the Fautau table.

#### COMPARISON OF SINISTRAL AND DEXTRAL GROUPS.

Following the order of treatment in the case of *P. otaheitana otaheitana*, we may consider first the proportionate numbers of the direct and reversed snails (table 65). The 1906 series shows an astonishing preponderance of sinistral individuals, while the series of the other two years agree more closely with one another and with the figures for 1899, as given by Mayer. The adolescent snails in my collections outnumber the adults for 1906; when the two groups are combined the percentage of reversed individuals rises to the high figure of 74 per cent.

TABLE 65.—*Partula otaheitana amabilis*, Hamuta Valley. Numerical relations of form-classes.

Series.	Adults.		Adolescents.		Adults and adolescents.		Embryonic young.	
	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.
1909, sinistral.....	20	68.9	4	57.1	24	66.6	42	87.5
dextral.....	9	31.0	3	42.8	12	33.3	6	12.5
1907, sinistral.....	240	61.4	72	62.0	312	61.5	167	57.7
dextral.....	151	38.6	44	37.9	195	38.4	112	42.2
1906, sinistral.....	39	88.6	62	68.1	101	74.8	7	100
dextral.....	15	11.3	29	31.8	34	25.1	0	0
1909-1906, sinistral.....	299	63.0	138	64.5	437	63.5	216	64.6
dextral.....	175	36.9	76	35.5	251	36.4	118	35.3
1899 [Mayer], sinistral...	...	69	...	....	...	....	...	73
dextral.....	...	31	...	....	...	....	...	27

Why the embryonic young of 1906 and 1909 should show so great an excess of sinistral individuals is difficult to conjecture. Such a result might be due to a higher rate of multiplication on the part of this type, and apparently some support for that interpretation is afforded by the figures for fecundity (table 66), which give *in all cases* an average above that for the dextral adults when the two form-classes are compared year by year. Yet when the average number of young for the entire series of a given year is taken into account, together with the percentage of gravid individuals in the whole series, it appears that the sinistral snails breed over a

longer period of the year, while the dextral snails exercise their reproductive ability from the end of the wet season onward, like the Fautaua colony. The 1906 specimens were secured in February and March, and the sinistral members were gravid in 79 per cent of the cases, while the contrasted groups showed only 54 per cent of its members in the same condition; in 1907, when the collections were obtained in July, the gravid dextrals far outnumbered the gravid reversed individuals—76 per cent as compared with 69 per cent; finally, in 1909, the former have again fallen below the latter in relative productivity. Hence the second interpretation suggested seems to have more in its favor than the supposition that different hereditary rates in fecundity distinguish the snails of the two kinds of coil.

TABLE 66.—*Partula otaheitana amabilis*, Hamuta Valley. Fecundity.

Series.	Records.	No. of gravid.	Per cent of gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.
Sinistral, 1906.....	38	30	78.95	14	40	54	1.80	1.42
1907.....	229	159	69.43	243	165	408	2.56	1.78
1909.....	5	4	80.00	6	6	12	3.00	2.40
Dextral, 1906.....	13	7	53.84	3	8	11	1.57	0.84
1907.....	149	113	75.84	171	114	285	2.52	1.91
1909.....	9	5	55.55	8	1	9	1.80	1.00
Sinistral, all years.....	272	193	70.95	263	211	474	2.45	1.74
Dextral, all years.....	171	125	73.09	182	123	305	2.44	1.78
Sinistral and dextral, 1906.....	51	37	72.55	17	48	65	1.75	1.27
1907.....	378	272	71.95	414	279	693	2.55	1.83
1909.....	14	9	64.28	14	7	21	2.33	1.50
Sinistral and dextral, all years.....	443	318	71.78	445	334	779	2.45	1.75

TABLE 67.—*Partula otaheitana amabilis*, Hamuta Valley. Numerical relations of the form and color classes.

Series.	No.	No. of plain.				No. of banded.	Percentage of plain.				Per cent banded.
		Class I.	Class II.	Class III.	Class IV.		Class I.	Class II.	Class III.	Class IV.	
Sinistral, 1906.....	39	4	5	28	2	..	10.2	12.8	71.8	5.1	...
1907.....	240	27	43	134	31	5	11.2	17.9	55.8	12.9	2.1
1909.....	20	2	4	10	3	1	10.0	20.0	50.0	15.0	5.0
Dextral, 1906.....	15	1	..	14	..	..	6.6	....	93.3	....	...
1907.....	151	34	25	73	17	2	22.5	16.5	48.3	11.2	1.3
1909.....	9	..	2	5	2	..	....	22.2	55.5	22.2	...
Sinistral, all.....	299	33	52	172	36	6	11.0	17.3	57.5	12.0	2.0
Dextral, all.....	175	35	27	92	19	2	20.0	15.4	52.5	10.8	1.1
Total.....	474	68	79	264	55	8	14.3	16.6	55.7	11.6	1.7

It has already been pointed out that Garrett describes the valley colony as composed of sinistral snails only, as far as this species is concerned. Either Garrett's mind was focussed on the Pirai Valley situation, or else a great change has been effected through the mutative production of dextral individuals by reversed parents. Garrett is so meticulous in his descriptions that I am somewhat inclined to adopt the latter view.

The color analysis of the sinistral and dextral divisions of the colony shows that they differ from one another more than the corresponding divisions of the Fautaua colony (table 67; compare with table 60), but it is questionable whether a fuller series of shells would show the same discrepancies. Probably the 6 per cent of dextral Class I shells in 1906 and the zero for 1909 would increase to a figure much nearer to the 22 per cent of 1907; the percentages for the sinistral shells are far more uniform, although even they are less consistent, especially in the case of Class IV, than in the fuller series from Fautaua. A point of special interest is that Class III in both coils is close to 50 per cent, as it is in the first-described valley; there is a great decrease in this respect when the next valley of Pirai is reached.

The significant statistical data relating to the standard dimensions of the two classes are given in table 68. On the whole, the dextral shells agree quite closely with the others, much more so than in Fautaua Valley. In length only are the former larger with statistical significance, where the difference exceeds thrice its error. In only two of the seven characters do the sinistral shells differ from the dextral group in the same way as in the Fautaua colony; these are, namely, the total length of the shell and length of aperture. In all of the other characters there is a reversed relation, or else the difference in the Hamuta colony is devoid of statistical significance.

TABLE 68.—*Partula otaheitana amabilis*, Hamuta Valley. Comparison of sinistral and dextral classes.

Character.	Sinistral (289).		Dextral (166).		Differences.	
	Mean value.	Standard deviation.	Mean value.	Standard deviation.	Mean value.	Standard deviation.
Shell, length, mm. ....	18.3282 ± .0332	0.8359 ± .0235	18.5018 ± .0475	0.9070 ± .0336	-0.1736 ± .0579	+0.0711 ± .0406
width, mm. ....	10.7097 ± .0172	.4396 ± .0122	10.7844 ± .0262	.5000 ± .0185	-.0747 ± .0313	-.0604 ± .0221
proportions, p. ct. ....	58.4100 ± .0928	2.3409 ± .0656	58.1988 ± .1118	2.1353 ± .0790	+ .2112 ± .1453	+ .2056 ± .1027
Aperture, length, mm. .	9.5617 ± .0190	.4833 ± .0134	9.6506 ± .0284	.5433 ± .0201	-.0889 ± .0341	-.0600 ± .0241
width, mm. .	7.4979 ± .0160	.4080 ± .0113	7.5386 ± .0216	.4130 ± .0152	-.0407 ± .0268	-.0050 ± .0189
proportions, p. ct. ....	78.2301 ± .1125	2.8388 ± .0795	78.0361 ± .1497	2.8594 ± .1058	+ .1940 ± .1872	-.0186 ± .1323
Length aperture ÷ length shell, propor- tions, p. ct. ....	52.0467 ± .0785	1.9788 ± .0555	52.1144 ± .0929	1.7756 ± .0657	-.0677 ± .1216	+ .2032 ± .0860

#### COMPARISON OF THE COLOR-CLASSES.

It is unnecessary to add materially to the statements made earlier regarding the varying proportion of sinistral and dextral specimens belonging to the several color-classes. Banded examples occur here with both modes of coil; in Fautaua the only specimens of this pattern were sinistral. The full statistical description of the several subdivisions is given in table 69. Aside from the difference between the direct and the reversed classes of shells, already dealt with, the most striking point is that the banded specimens are quite peculiar, as compared with the plain shells of corresponding twist.



TABLE 69.—*Partula otaheitana amabilis*, Hamuta Valley. Analysis of the color-classes.

MEAN VALUE.								
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.	
		<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>p. ct.</i>
Sin., plain, I.	30	18.1200 ± .0779	10.6200 ± .0553	58.4667 ± .2744	9.4267 ± .0601	7.4200 ± .0474	78.3000 ± .3170	51.7333 ± .2891
II.	52	18.3500 ± .1023	10.7039 ± .0445	58.2500 ± .2192	9.6039 ± .0469	7.4693 ± .0401	77.6731 ± .2520	52.2115 ± .1571
III.	165	18.3591 ± .0456	10.7206 ± .0226	58.3727 ± .1175	9.5776 ± .0241	7.5158 ± .0206	78.2212 ± .1540	52.0818 ± .1000
IV.	36	18.3584 ± .0937	10.7056 ± .0518	57.7222 ± .3145	9.5000 ± .0579	7.4778 ± .0488	78.7778 ± .3051	51.6111 ± .2132
Sin., banded..	6	18.1500 ± .1763	10.9333 ± .1472	61.0000 ± .8958	9.8000 ± .1549	7.7667 ± .1175	79.6667 ± .6036	53.8333 ± .8804
Sin., plain, all.	283	18.3320 ± .0336	10.7049 ± .0179	58.3551 ± .0917	9.5565 ± .0193	7.4922 ± .0163	78.1996 ± .1140	52.0088 ± .0773
Sin., all.....	289	18.3282 ± .0332	10.7097 ± .0172	58.4100 ± .0928	9.5617 ± .0190	7.4879 ± .0160	78.2301 ± .1125	52.0467 ± .0785
Dex., plain, I.	34	18.4205 ± .0833	10.7765 ± .0452	58.5588 ± .2135	9.6647 ± .0568	7.5706 ± .0452	78.2059 ± .3155	52.5000 ± .2023
II.	24	18.3875 ± .1257	10.7750 ± .0609	58.7500 ± .2789	9.5917 ± .0818	7.5417 ± .0739	78.4166 ± .3394	52.1667 ± .2439
III.	88	18.5819 ± .0686	10.8296 ± .0373	58.0795 ± .1520	9.6750 ± .0360	7.5569 ± .0283	78.0681 ± .2013	51.9886 ± .1382
IV.	18	18.4500 ± .1558	10.5889 ± .0919	57.3333 ± .3820	9.6112 ± .1056	7.4223 ± .0842	77.2778 ± .5866	52.0000 ± .3056
Dex., banded..	2	18.2000 ± .0715	10.8000 ± .2478	58.5000 ± 1.4308	9.4000 ± .1431	7.2000 ± .1431	76.0000 ± .2385	51.5000 ± .9539
Dex., plain, all.	164	18.5055 ± .0480	10.7848 ± .0263	58.1951 ± .1118	9.6537 ± .0287	7.5423 ± .0217	78.1610 ± .1510	52.1220 ± .0933
Dex., all.....	166	18.5018 ± .0475	10.7844 ± .0262	58.1988 ± .1118	9.6506 ± .0284	7.5386 ± .0216	78.0361 ± .1497	52.1144 ± .0929
STANDARD DEVIATION.								
Sin., plain, I.	30	0.6325 ± .0551	0.4489 ± .0391	2.2283 ± .1840	0.4885 ± .0425	0.3850 ± .0335	2.5742 ± .2241	2.3478 ± .2044
II.	52	1.0944 ± .0723	.4764 ± .0314	2.3442 ± .1550	.5015 ± .0332	.4286 ± .0283	2.6941 ± .1782	1.6795 ± .1111
III.	165	.8685 ± .0322	.4313 ± .0160	2.2379 ± .0831	.4590 ± .0170	.3931 ± .0146	2.9328 ± .1089	1.9039 ± .0707
IV.	36	.8411 ± .0662	.4606 ± .0366	2.8049 ± .2224	.5142 ± .0409	.4340 ± .0345	2.7142 ± .2157	1.8970 ± .1508
Sin., banded..	6	.6403 ± .1247	.5344 ± .1041	3.2532 ± .6334	.5627 ± .1095	.4269 ± .0831	2.1921 ± .4268	3.1972 ± .6225
Sin., plain, all.	283	.8390 ± .0238	.4465 ± .0126	2.2861 ± .0648	.4804 ± .0136	.4057 ± .0115	2.8430 ± .0806	1.9268 ± .0546
Sin., all.....	289	.8359 ± .0235	.4396 ± .0122	2.3409 ± .0656	.4833 ± .0134	.4080 ± .0113	2.8388 ± .0795	1.9788 ± .0555
Dex., plain, I.	34	.7204 ± .0589	.3911 ± .0319	1.8462 ± .1510	.4910 ± .0402	.3907 ± .0319	2.7281 ± .2231	1.7489 ± .1430
II.	24	.9132 ± .0889	.4428 ± .0431	2.0258 ± .1972	.5944 ± .0578	.3915 ± .0522	2.4650 ± .2400	1.7716 ± .1724
III.	88	.9538 ± .0485	.5240 ± .0264	2.1144 ± .1075	.5016 ± .0254	.3942 ± .0200	2.7993 ± .1423	1.7254 ± .0977
IV.	18	.9798 ± .1102	.5782 ± .0650	2.4095 ± .2701	.6641 ± .0746	.5298 ± .0595	3.6901 ± .4148	1.9221 ± .2161
Dex., banded..	2	.1500 ± .0505	.5196 ± .1752	3.0000 ± 1.0117	.3000 ± .1012	.3000 ± .1012	0.5000 ± .1686	2.0000 ± .6745
Dex., plain, all.	164	.9118 ± .0339	.4999 ± .0186	2.1224 ± .0791	.5449 ± .0203	.4124 ± .0153	2.8673 ± .1068	1.7712 ± .0660
Dex., all.....	166	.9070 ± .0336	.5000 ± .0185	2.1353 ± .0790	.5433 ± .0201	.4130 ± .0152	2.8594 ± .1058	1.7756 ± .0657

It appears that the dextral and sinistral groups of banded specimens differ from the comparable divisions of unbanded shells in totally unlike ways. The reversed shells are about the same in length, decidedly wider, and very much stouter, while in the characters of the aperture they display greater length, greater width, and somewhat rounder proportions; it follows that the proportion of aperture-length to shell-length is much higher. On the other hand, the dextral banded individuals have comparatively shorter shells and distinctively shorter and narrower apertures that are relatively narrowed also; the proportion of aperture to shell in length is *less* than that of the plain shells. It does not seem, then, that the direct and reversed shells with bands are very similar in statistical respects, or that they constitute a subtype that is essentially independent of the prevalent unstriped kind. Again it may be pointed out that if such snails are sports from the plain stock, as they appear to be, they would be likely to arise from parents at widely separated positions on the graduated scale of variation; therefore their mean in any one character would tend

to be different from the general average, and their variability would be unusually high. Such are the facts.

The color-classes of the plain shells differ among themselves and in various ways in the several characters. There is no simple generalization that can be formulated.

The statistics relating to the tooth (table 70) show no very significant differences between comparable classes.

TABLE 70.—*Partula otaheitana amabilis*, Hamuta Valley. Statistics of tooth-development.

	No.	Distribution.					Constants.	
		None. (1)	Trace. (2)	Tooth. (3)	Large. (4)	Very large. (5)	Mean.	Standard deviation.
Sinistral, plain, I.....	33	1	2	20	10	0	3.1818±.0789	0.6721±.0558
II.....	52	2	2	31	17	0	3.2115±.0664	.6888±.0469
III.....	172	9	12	109	41	1	3.0755±.0376	.7314±.0266
IV.....	36	0	6	24	6	0	3.0000±.0649	.5773±.0459
Sinistral, banded.....	6	1	1	4	0	0	2.5000±.2102	.7637±.1486
Sinistral, plain, all.....	293	12	22	184	74	1	3.1024±.0277	.7033±.0196
Sinistral, all.....	299	13	23	188	74	1	3.0903±.0276	.7096±.0195
Dextral, plain, I.....	35	1	4	19	11	0	3.1428±.0801	.7027±.0566
II.....	27	3	3	15	6	0	2.8889±.1135	.8749±.0802
III.....	92	4	11	57	20	0	3.0109±.0502	.7146±.0355
IV.....	19	1	2	14	1	0	2.8947±.1247	.6403±.0882
Dextral, banded.....	2	..	1	1	0	0	2.5000±.2384	.5000±.1686
Dextral, plain, all.....	173	9	20	105	39	0	3.0058±.0380	.7410±.0269
Dextral, all.....	175	9	21	106	39	0	3.0000±.0377	.7407±.0266

#### HEREDITY.

As in the case of the generalized stock of Fautaua Valley, in Hamuta there are snails of each coil which produce young of the opposite nature (table 71). The total percentage of sinistral young is so slightly in excess of the figures for the adults that no significance attaches to the difference.

The inheritance of the fundamental ground-color, on the basis of the data in hand, is by no means so close as one might expect. Too much weight should not be laid upon the figures in question, on account of the difficulty in deciding upon the exact class to which an embryonic snail should be assigned, for such snails do not establish their definitive colors as early as they do in the Fautaua colony. In addition, the deeply-tinged apex is exhibited by a large proportion of the shells of the lighter color-classes, and as the tinged apex appears in the very young condition there is some tendency to refer such individuals to a darker color-class—obviously an erroneous assignment. It is not so much an error in observation as a difficulty in the material that accounts for the lack of stricter heredity in the statistics as tabulated.

The banded character is exhibited by 1 out of 6 produced by adults of this kind. The indicated absence of banded sports among the young of plain parents may be accounted for by the translucence of the embryonic shell.

TABLE 71.—*Partula otaheitana amabilis*, Hamuta Valley.

Form and color-classes of adults.		FULL STATISTICS OF HEREDITY.										
		Color-class, sinistral young.					Color-class, dextral young.					Total.
		Plain.				Banded.	Plain.				Banded.	
		I.	II.	III.	IV.		I.	II.	III.	IV.		
Sinistral, plain, I.....	7	1	2	5	..	6	..	..	..	..	21	
II.....	4	..	13	16	..	3	1	1	3	..	41	
III.....	8	8	20	59	..	7	..	4	16	..	122	
IV.....	1	1	2	10	..	2	..	..	5	..	21	
Sinistral, banded.....	..	..	..	4	1	..	1	..	..	..	6	
Sinistral, all.....	21	10	37	94	1	18	2	5	24	..	211	
	162					49						
Dextral, plain, I.....	10	1	3	1	..	6	1	2	3	..	27	
II.....	2	2	..	2	..	3	3	4	5	..	21	
III.....	7	..	2	16	..	9	1	4	22	..	61	
IV.....	2	2	..	3	..	1	..	1	4	..	13	
Dextral, banded.....	..	..	..	1	..	..	..	..	..	..	1	
Dextral, all.....	21	5	5	23	..	19	5	11	34	..	123	
	54					69						
	42	15	42	117	1	37	7	16	58	0	334	
Total.....	216					118						

HEREDITY OF COLOR-CHARACTERS.							HEREDITY OF COIL.				
	Young.							Young.			
	Plain.				Banded.	Total.		Sinistral.	Dextral.	Total.	
	I.	II.	III.	IV.							
Adults:							Adults:				
Plain, I.....	29	3	7	9	..	48	Sinistral....	162	49	211	
II.....	12	6	18	26	..	62				[63.17 p. ct.]	
III.....	31	9	30	113	..	183	Dextral....	54	69	123	
IV.....	6	3	3	22	..	34				[36.82 p. ct.]	
Banded.....	..	1	..	5	1	7	Total.....	216	118	334	
Total.....	78	22	58	175	1	334		[64.67 p. ct.]	[35.32 p. ct.]		

## CONCLUSION.

The collective population of Hamuta Valley presents an aspect quite similar to that of the fundamental colony in Fautaua Valley. In fact, *P. otaheitana amabilis* in this region is far closer to the original stock than any other colony of the entire island. Nevertheless, the Hamuta association exhibits distinctive features, both as regards the relative numbers of sinistral and dextral individuals, and also in the dimensions and proportions of the shell and aperture. As a whole, it forms a different hereditary complex, whose characteristics can not be attributed to environmental peculiarities, for these are absolutely identical with those of Fautaua and of Pirai Valley on the west. Isolation merely keeps its characters intact, so to speak, as a condition and not as a cause of differentiation.

## PIRAI VALLEY.

Pirai Valley, as the sole area inhabited by *P. filosa*, has been described at some length at an earlier juncture (pp. 82, 83), where its distinctive features and the recent changes in the aspect of its vegetation in the lower portion have been noted.

The representatives of *P. o. amabilis* which have been collected here are of considerable interest, especially because this is the only valley in which collections were made in all four years of field work. The four annual series were obtained in different parts of the long valley, those of 1906 from near the mouth because the cyclonic disturbance previously mentioned made progress into the interior all but impossible; in 1907 further ingress was feasible, and in later years collections were made still farther inland, very nearly if not quite to the highest limit of the area inhabited by Partulæ. It is possible, therefore, to compare different sections of the whole population, and it appears that, as in *filosa*, these sections are statistically different in certain respects.

Only sinistral specimens were found in a series of 1,467 adult and adolescent individuals brought back for detailed study, in addition to some 400 others which were taken in 1909 and after examination were returned to their environment. We may be reasonably sure, then, that dextral specimens do not occur at present, and also that none have occurred for many decades, because Mayer obtained 131 adults which were all sinistral, while Garrett explicitly states that no dextral shells were found by him. It will be interesting to ascertain the state of affairs in Pirai Valley after the lapse of 25, 50, or 100 years, to see if the direct shells make their appearance; and, if they do, whether they arise spontaneously by mutation or migrate from another valley.

Although the four color-classes of the previously described valley recur here (plate 26, figs. 1 to 16), the general complexion of the colony as a whole is decidedly distinctive, for the darker-colored shells of Classes III and IV (plate 26, figs. 9 to 16) are greatly diminished in numbers. Among those of Class I (plate 26, figs. 1 to 8) a well-marked group of nearly pure white shells exists (Ia) (figs. 1 to 4) as a result of general decortication. Such specimens are very few in Hamuta and still rarer in Fautaua.

## COMPARISON OF THE ANNUAL SERIES.

The four annual series represent the populations of as many sections of the inhabited area, in regular order from the coastward to the most inland. The proportionate numbers of the several color-classes change greatly in passing from the outer to the inner sections (table 72). Class I is the most richly represented, and it increases steadily from 60.5 to 84.2 per cent, although subclass Ia remains about the same; it follows, then, that decortication occurs in a larger number of Class I shells in the lower part of the valley than it does in the interior. Class III is very poorly represented, while only one entirely brown snail was secured in the highest part of the valley. Banded shells (plate 26, fig. 17) occur sparsely, on the whole in about the same relative numbers as in Hamuta; they are all sinistral.

TABLE 72.—*Partula otaheitana amabilis*, Pirai Valley. Numerical relations of the color-classes.

Series.	No.	No. of plain.				No. of banded.	Percentage of plain.				Per cent banded.
		Class I.	Class II.	Class III.	Class IV.		Class I.	Class II.	Class III.	Class IV.	
1906	291	$\begin{smallmatrix} a & b \\ 176 \end{smallmatrix}$	[(104) 107 (3)]		..	8	$\begin{smallmatrix} a & b \\ 60.5 \end{smallmatrix}$	[(35.7) 36.7 (1.0)]		...	2.7
1907	252	$\begin{smallmatrix} 52 & 115 \\ \hline 167 \end{smallmatrix}$	82	2	..	1	$\begin{smallmatrix} 20.6 & 45.6 \\ \hline 66.2 \end{smallmatrix}$	32.5	0.8	...	0.4
1908	83	$\begin{smallmatrix} 14 & 48 \\ \hline 62 \end{smallmatrix}$	10	3	..	8	$\begin{smallmatrix} 16.8 & 57.8 \\ \hline 74.6 \end{smallmatrix}$	12.0	3.6	...	9.6
1909	362	$\begin{smallmatrix} 61 & 244 \\ \hline 305 \end{smallmatrix}$	49	5	1	2	$\begin{smallmatrix} 16.8 & 67.4 \\ \hline 84.2 \end{smallmatrix}$	13.5	1.5	0.2	0.5
		710	245	13	1		71.8	24.8	1.3	0.1	
All	988	969				19	98.0				1.9

TABLE 73.—*Partula otaheitana amabilis*, Pirai Valley. Statistical comparison of annual series.

MEAN VALUE.								
Group.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.	
		<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>p. ct.</i>
Plain, 1906....	266	18.7493±.0407	10.9263±.0200	58.1917±.0831	9.7602±.0207	7.6038±.0164	77.9436±.1156	51.9924±.0785
1907....	233	18.4092±.0428	10.7243±.0203	58.1738±.1017	9.5035±.0213	7.4116±.0175	78.0021±.1128	51.5129±.0801
1908....	72	18.2625±.0729	10.6195±.0311	58.1250±.1894	9.4806±.0364	7.3250±.0304	77.1389±.2106	51.8750±.1386
1909....	349	17.8368±.0320	10.4352±.0167	58.4942±.0840	9.2072±.0170	7.1768±.0147	77.9412±.1095	51.5573±.0657
Plain, all.....	920	18.2789±.0225	10.6648±.0112	58.2967±.0533	9.4635±.0118	7.3713±.0096	77.8946±.0629	51.6967±.0411
Banded, 1906..	8	18.7250±.1326	10.9750±.0682	58.5000±.7154	9.6500±.0572	7.6000±.0533	78.2500±.6503	51.5000±.3770
1908..	8	17.6375±.3501	10.4250±.0858	59.0000±.3954	9.1000±.1262	7.0750±.0906	78.0000±.6080	51.3750±.2780
Banded, all yrs. <sup>1</sup>	19	18.3184±.1396	10.7105±.0741	58.4474±.3705	9.4474±.0790	7.3947±.0638	78.0789±.3960	51.5000±.2130
All.....	939	18.2797±.0222	10.6657±.0111	58.2998±.0528	9.4632±.0117	7.3718±.0097	77.8983±.0621	51.6927±.0405
STANDARD DEVIATION.								
Plain, 1906....	266	0.9835±.0287	0.4838±.0141	2.2509±.0587	0.5023±.0146	0.3982±.0116	2.7961±.0817	1.8983±.0555
1907....	233	.9689±.0302	.4607±.0144	2.3024±.0719	.4829±.0151	.3973±.0124	2.5541±.0798	1.8139±.0566
1908....	72	.9171±.0515	.3911±.0220	2.3829±.1339	.4585±.0257	.3829±.0215	2.6498±.1489	1.7435±.0980
1909....	349	.8862±.0226	.4620±.0118	2.3284±.0594	.4704±.0120	.4082±.0104	3.0346±.0774	1.8190±.0464
Plain, all.....	920	1.0117±.0159	.5052±.0079	2.3977±.0377	.5320±.0083	.4327±.0068	2.8291±.0445	1.8473±.0291
Banded, 1906..	8	.5562±.0937	.2861±.0482	3.0000±.5058	.2398±.0404	.2236±.0377	2.7272±.4598	1.5811±.2666
1908..	8	1.4682±.2475	.3597±.0607	1.6583±.2796	.5291±.0892	.3799±.0640	2.5495±.4299	1.1659±.1966
Banded, all yrs. <sup>1</sup>	19	.9020±.0987	.4789±.0524	2.3945±.2620	.5103±.0559	.4122±.0451	2.5592±.2800	1.3765±.1506
All.....	939	1.0096±.0157	.5047±.0078	2.3977±.0373	.5317±.0083	.4324±.0069	2.8229±.0439	1.8391±.0286

<sup>1</sup>Includes 1 banded snail of 1907 and 2 of 1909.

The statistical comparison of the annual series is given in detail in tables 73 and 74, which also include the constants for the whole population, to be used in the summary. The results are extremely interesting. While the proportionate measures and the tooth remain about the same, there is a regular and progressive diminution in the absolute dimensions of the whole shell and of the aperture; even the short series of banded shells for 1906 and 1908 exhibit precisely the same statistical differences as the larger series of plain individuals. This result is in exact accord with the findings in the case of *P. filosa*, the small dextral species confined to this valley. Why the snails of both species should be absolutely smaller in the more favorable higher portion of the valley, and larger where the conditions are adverse, is difficult to understand. The only reasonable suggestion, to my mind, is that selection weeds out the smaller snails in the coastward area, leaving only the larger and more vigorous individuals; the absence of so rigid an eliminative process higher up leads to a reduction of the average measures through the survival of smaller individuals. This species is more abundant inland, which lends some support to the tentative interpretation given.

TABLE 74.—*Partula otaheitana amabilis*, Pirai Valley. Statistics of tooth development.

Series.	No.	None.	Trace.	Tooth.	Large.	Very large.	Mean value.	Standard deviation.
Sinistral, plain, 1906. ....	176	14	26	108	23	5	2.8807±.0424	0.8342±.0300
1907. ....	250	14	41	179	10	6	2.8120±.0298	.6990±.0211
1908. ....	75	2	13	47	9	4	3.0000±.0611	.7831±.0432
1909. ....	360	20	50	239	33	18	2.9417±.0286	.8058±.0202
Sinistral, plain, all years. ....	861	50	130	573	75	33	2.8966±.0180	.7829±.0127
Sinistral, banded, 1906. ....	8	0	2	6	0	0	2.7500±.1032	.4330±.0730
1908. ....	8	0	1	7	0	0	2.8750±.0788	.3306±.0557
Sinistral, banded, all years <sup>1</sup> . .	19	0	3	15	1	0	2.8948±.0691	.4466±.0488
Sinistral, all. ....	880	50	133	588	76	33	2.8966±.0177	.7772±.0125

<sup>1</sup>Includes 1 banded snail of 1907 and 2 of 1909.

## COMPARISON OF THE COLOR-CLASSES.

In comparing statistically the several distinguishable color-groups (table 75) it is obligatory to disregard the series of 1906, as deteriorated preservative altered the colors of Classes II and III; the series of 1908 may be also omitted on account of its smallness. There remain the groups of 1907 and 1909, in both of which the Class I shells greatly predominate. The figures show how the specimens assigned to the darker classes depart from those of Class I.

As we have seen, the inland group of 1909 comprises individuals that are smaller than those of the lower valley, while at the same time Class I is relatively more abundant. It is true that this group is made up of smaller shells in the coastward section, and it might be supposed that the reduced averages of the 1909 series would be due simply to the greater prevalence of small, light-colored shells; but this is not so. The snails of Class II are also reduced in size in passing inland, and in addition the statistics relating to the banded examples, given in table 73, show

again the same diminution, in a third instance. In brief, the changes observed are consistently displayed by all the groups that are sufficiently numerous to give satisfactory statistics, and the class differences of a given year are secondary in importance in this connection.

TABLE 75.—*Partula otaheitana amabilis*, Pirai Valley. Analysis of the color-classes of 1907 and 1909.

MEAN VALUE.									
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
		mm.	mm.	p. ct.	mm.	mm.	p. ct.	p. ct.	
1907, I.	157	18.2905 ± .0511	10.7242 ± .0244	58.3726 ± .1164	9.4962 ± .0264	7.4032 ± .0218	77.9331 ± .1324	51.6592 ± .0958	2.8144 ± .0373
II.	75	18.4960 ± .0816	10.7294 ± .0362	57.8066 ± .1980	9.5187 ± .0355	7.4360 ± .0293	78.2333 ± .2058	51.2200 ± .1450	2.8049 ± .0599
III.	1	18.9500	10.3000 ±	54.5000	9.5000	7.6200 ±	76.9000	50.5000	3.000
1907, all.	233	18.4092 ± .0428	10.7243 ± .0203	58.1738 ± .1017	9.5035 ± .0213	7.4116 ± .0175	78.0021 ± .1128	51.5129 ± .0801	2.8120 ± .0298
1909, I.	296	17.7881 ± .0337	10.4372 ± .0179	58.4966 ± .0891	9.2169 ± .0181	7.1845 ± .0152	77.9966 ± .1188	51.6148 ± .0696	2.9672 ± .0311
II.	47	17.7319 ± .0903	10.4106 ± .0439	58.5000 ± .2595	9.1298 ± .0431	7.1085 ± .0382	77.5212 ± .3091	51.2234 ± .2057	2.8776 ± .0572
III.	5	17.9400 ± .4968	10.4600 ± .2235	58.3000 ± .7958	9.3000 ± .2778	7.3400 ± .2104	79.1000 ± .4901	51.7000 ± .3518	2.4000 ± .2413
IV.	1	19.2500 ±	10.9000	58.5000	9.8600	7.6600	75.5000	49.5000	2.8000
1909, all.	349	17.8368 ± .0320	10.4352 ± .0167	58.4942 ± .0840	9.2072 ± .0170	7.1768 ± .0147	77.9412 ± .1095	51.5573 ± .0657	2.9417 ± .0286
STANDARD DEVIATION.									
1907, I.	157	0.9458 ± .0361	0.4533 ± .0172	2.1436 ± .0821	0.4912 ± .0187	0.4061 ± .0154	2.4605 ± .0936	1.7792 ± .0677	0.7144 ± .0265
II.	75	1.0467 ± .0577	.4774 ± .0256	2.5402 ± .1401	.4677 ± .0251	.3755 ± .0207	2.6393 ± .1455	1.8587 ± .1025	.6704 ± .0423
1907, all.	233	.9689 ± .0302	.4607 ± .0144	2.3024 ± .0719	.4829 ± .0151	.3973 ± .0124	2.5541 ± .0798	1.8139 ± .0566	.6990 ± .0211
1909, I.	296	.8593 ± .0238	.4582 ± .0119	2.2723 ± .0630	.4632 ± .0128	.3891 ± .0107	3.0302 ± .0840	1.7745 ± .0492	.8050 ± .0220
II.	47	.9183 ± .0638	.4458 ± .0310	2.6377 ± .1835	.4385 ± .0305	.3869 ± .0270	3.1318 ± .2185	2.0905 ± .1454	.5936 ± .0404
III.	5	1.6470 ± .3513	.7411 ± .1580	2.6382 ± .4920	.9209 ± .1964	.6974 ± .1488	1.6248 ± .3465	1.1662 ± .2487	.8000 ± .1706
1909, all.	349	.8862 ± .0226	.4620 ± .0118	2.3284 ± .0594	.4704 ± .0120	.4082 ± .0104	3.0346 ± .0774	1.8190 ± .0464	.8058 ± .0202

#### FECUNDITY.

In reproductive ability (table 76) the several annual series are alike to a degree that is remarkable in view of the differences in the seasons of their capture. Nearly 70 per cent of the snails taken in the wet season of 1906 were bearing, while only 50 per cent of the 1909 collection, secured during the dry season, were fertile. The eggs are fewer in proportion to the number of young, in the former case, and it would seem that about the beginning of the dry season the snails began upon a new period of reproductive activity. Nevertheless, no generalization is justified on the basis of the observations on the snails of a single valley taken at such widely separated intervals of time.

#### HEREDITY.

On account of the faint coloration of embryonic shells, their exact classification on a color-basis is difficult. The statistics of heredity, as given in table 77, may not be entirely trustworthy, but they show conclusively that the banded character appears in offspring of plain parents, and that banded adults produce both kinds of young snails. The members of Class III contribute light-colored young to

Classes I and II, while the dark classes receive recruits from light-colored divisions. Interbreeding among the members of the several classes seems to occur; at least the recognizable divisions are not absolutely isolated in an hereditary sense.

TABLE 76.—*Partula otaheitana amabilis*, Pirai Valley. Statistics of fecundity.

Series.	Record.	No. gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.
Sinistral, plain, 1906.....	138	93	67.39	60	138	198	2.13	1.43
1907.....	249	155	62.25	268	120	388	2.50	1.56
1908.....	74	56	75.68	72	59	131	2.34	1.77
1909.....	360	190	50.50	320	110	430	2.26	1.19
Sinistral, plain, all.....	821	494	60.17	720	427	1,147	2.32	1.39
Sinistral, banded, 1906....	3	3	100	0	5	5	1.67	1.67
1907....	1	1	100	2	1	3	3.00	3.00
1908....	4	3	75	3	4	7	2.33	1.75
1909....	2	2	100	4	1	5	2.50	2.50
Sinistral, banded, all.....	10	9	90	9	11	20	2.22	2.00
All.....	831	503	60.53	729	438	1,167	2.32	1.40

TABLE 77.—*Partula otaheitana amabilis*, Pirai Valley. Heredity.

FULL DATA.					SUMMARY.			
	Young.					Young.		
	Classes I and II.	Classes III and IV.	Banded.	Total.		Plain.	Banded.	Total.
Adults:					Adults:			
Plain, Class I...	350	5	..	355	Plain....	426	1	427
II...	61	3	1	65				[97.48 p. ct.]
III...	4	3	..	7	Banded..	7	4	11
IV...	..	..	..	..				[2.51 p. ct.]
Banded.....	7	..	4	11	Total....	433	5	438
Total.....	422	11	5	438		[98.85 p. ct.]	[1.14 p. ct.]	.

## CONCLUSION.

In its collective aspect, *P. o. amabilis* of Pirai Valley departs from the Fautaua association to a greater degree than does the colony of Hamuta. Its distinctive features are (1) the absence of dextral components; (2) the preponderance of light-colored shells; and (3) smaller dimensions in all sections of the colony. The last-named quality is one that will appear more clearly in the summary treatment of the whole variety.

## POHAITARA VALLEY.

The northern geographical sector, between Pirai and Tuauru Valleys, contains several narrow gullies or ravines of considerable radial extent, but of relatively shallow depth. The stream-bed rises rapidly as it is followed inland, so that its gradient is very nearly of the same angle as the profile slope of the ridges on either side. Valleys of this kind, which are relatively open and dry, belong to the quater-



nary class. Pohaitara Valley, in the district of Arue, is such a gully (plates 9, 10, and 11). When it divides, at about  $2\frac{1}{2}$  miles from the coast, the lesser division (Faaiti) trends toward Pirai Valley, while its larger division (Faaroa) bends eastward toward the upper end of Ururoa. It is unusually narrow, with steep and high sides in the interior, and supports little succulent vegetation.

The snails taken in this valley were found in numbers only in a restricted strip of territory bordering the broken-bedded stream, at some distance back from the coast; they occurred on *Freycinetia*, *Pandanus*, and "oaha," as well as on other bushes and trees in smaller numbers. The natives stated that many plantains and orange-trees grew on the heights above, but that no snails were to be found there. The barometric level of the area of collection was from 1,100 to 1,450 feet above the sea.

All of the specimens of *P. o. amabilis* taken here were sinistral. The distinguishable color-classes do not correspond with those of previously described colonies, although the primary variety is certainly the same as before. The chief difference is in the virtual absence of the reddish color-factors expressed most clearly in Class III shells of Fautaua, Hamuta, and Pirai. Here the shells fall into three divisions, namely, "light" (plate 26, figs. 18 to 22), "medium" (plate 26, figs. 23 to 30), and "dark" (plate 26, figs. 31 to 36). The first of these is intermediate between Classes I and II of Pirai, always lacking the tinted apex; the second is about midway between Classes II and III of Pirai, while the last is much like Class IV without the red tinge of many previous examples. Decortication sometimes results in a pinkish color of the shell (plate 26, fig. 30), but this is essentially different from the red hue of shells assigned to the darker classes in other valley colonies.

The numerical representation of the three classes is as follows:

The statistical data relating to the three divisions and to the colony as a whole are given in table 78. As compared with the Pirai series, there is a notable diminution in absolute measures, both of the whole shell and of the aperture; this is so great in the case of shell length as to render the figure for shell proportions far higher than in any other colony of *amabilis*.

	No. •	Per cent.
Light.....	65	16.8
Medium.....	188	48.6
Dark.....	134	34.6

Of the three color divisions the light class is the smallest, and the aperture length bears a noticeably higher proportion to the total length of the shell. The tooth (table 79) is least developed in the light shells.

In the matter of fecundity (table 80), the snails of this valley show a remarkably low percentage of gravid individuals (27.52 per cent) and a low degree of fertility among these; yet the animals were collected at a time when the colonies of neighboring valleys were actively breeding.

Only 25 young were sufficiently advanced to give data on heredity (table 80), all of which were sinistral like their parents. The dark snails bred true, but their class received additions from the other two groups of adults. Hence the color lines are not impassable, and the statistical differences of the tables do not signify that rigid differentiation has taken place within the colonial limits.

The distinctive features of this colony, as compared with that of Pirai, are: (1) the reduced size; (2) the lack of the reddish color-tones; and (3) the occurrence of numerous dark-brown individuals, which, although sinistral, approach the typical condition of the dextral *P. otaheitana affinis*.

TABLE 78.—*Partula otaheitana amabilis*, Pohaitara Valley. Comparison of the color-classes.

MEAN VALUE.								
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.	
		<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>p. ct.</i>
Light....	64	17.4078 ± .0740	10.5187 ± .0386	60.3125 ± .1999	9.2750 ± .0424	7.1750 ± .0317	77.4063 ± .2189	53.1250 ± .1559
Medium...	182	17.6181 ± .0394	10.4682 ± .0233	59.3517 ± .1000	9.2308 ± .0200	7.1956 ± .0190	77.5456 ± .1325	52.3517 ± .0933
Dark....	133	17.5560 ± .0428	10.4880 ± .0248	59.6504 ± .1968	9.2895 ± .0231	7.2023 ± .0212	77.4474 ± .1734	52.6504 ± .1091
All.....	379	17.5608 ± .0273	10.4836 ± .0156	59.6187 ± .0683	9.2588 ± .0144	7.1945 ± .0130	77.6847 ± .0984	52.5871 ± .0639
STANDARD DEVIATION.								
Light....	64	0.8776 ± .0532	0.4579 ± .0273	2.3709 ± .1413	0.5031 ± .0300	0.3766 ± .0224	2.5964 ± .1548	1.8498 ± .1102
Medium...	182	.7877 ± .0278	.4656 ± .0165	2.0011 ± .0707	.4003 ± .0141	.3807 ± .0134	2.8406 ± .0937	1.8659 ± .0660
Dark....	133	.7322 ± .0302	.4248 ± .0175	2.2661 ± .1391	.3949 ± .0163	.3626 ± .0150	2.9642 ± .1226	1.8658 ± .0771
All.....	379	.7885 ± .0193	.4508 ± .0110	1.9720 ± .0483	.4164 ± .0102	.3738 ± .0092	2.8401 ± .0696	1.8435 ± .0452

TABLE 79.—*Partula otaheitana amabilis*, Pohaitara Valley. Statistics of tooth-development.

Series.	No.	No tooth.	Trace.	Tooth.	Large.	Very large.	Mean value.	Standard deviation.
Light.....	65	10	14	36	5	..	2.5539 ± .0704	0.8418 ± .0498
Medium....	188	22	50	99	14	3	2.6064 ± .0416	.8470 ± .0294
Dark.....	134	14	26	80	12	2	2.7165 ± .0481	.8251 ± .0340
All.....	387	46	90	215	31	5	2.6357 ± .0288	.8408 ± .0203

TABLE 80.—*Partula otaheitana amabilis*, Pohaitara Valley.

FECUNDITY.		HEREDITY.				
			Light.	Medium.	Dark.	Total.
Gravid.....	101	Adults:				
Per cent gravid.....	27.52		Light.....	3	1	4
			Medium....	13	1	16
Eggs.....	126		Dark.....	..	5	5
Young.....	25	Total....	2	16	7	25
Total contents.....	151					
Average for growth.....	1.49					
Average for all.....	0.41					

## URUROA VALLEY.

Ururoa Valley, like Pohaitara, is a relatively shallow gully of steep gradient. It lies nearest to the main ridge or backbone of the mountain mass between Pirai and Tuauru Valleys—the spine, namely, that terminates at the steep bluffs of

Tahara immediately to the west of Point Venus (plates 9, 10, and 11). The snails of this area agree with those of Pohaitara most closely, but the series is remarkable because banded sports occur—3 out of 345—while 1 plain dextral individual was taken that corresponds with the prevalent forms in all respects save coil.

The three color-classes of Pohaitara occur here, although not in the same proportionate numbers; they are represented as follows:

<i>Sinistral:</i>	
Plain, light.....	50 (14.49 per cent).
medium.....	13 (3.77 per cent).
dark.....	278 (80.57 per cent).
decorticated.....	31 (8.98 per cent).
intact.....	247 (71.59 per cent).
<i>Sinistral:</i> Banded .....	3 (0.87 per cent).
<i>Dextral:</i> Plain .....	1 (0.29 per cent).

The light shells (plate 26, figs. 37 to 39) are all devoid of a tinted apex. The medium shells (plate 26, figs. 40 to 43) have the darker apex; they are few in numbers. The brown shells (plate 26, figs. 44 to 47) are decorticated in one-eighth of the cases; the rest, amounting to a little over 70 per cent, form the prevalent class. The banded specimens are like similarly colored shells from Pirai (plate 26, figs. 48 and 49), although none of the three displays a reddish tone, either in ground-color or in the band itself. The single dextral shell belonged to the medium class, with the darkened spire (plate 26, fig. 50).

TABLE 81.—*Partula otaheitana amabilis*, *Ururoa Valley*.

MEAN VALUE.								
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.	
		<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>p. ct.</i>
Sin., plain....	338	17.4526 ± .0299	10.3663 ± .0167	59.3462 ± .0862	9.2089 ± .0175	7.1408 ± .0142	77.5355 ± .1056	52.6657 ± .0691
banded..	2	16.7000 ± .2146	9.8000 ± .2385	58.5000 ± .4769	8.7000 ± .1908	6.7000 ± .2862	77.5000 ± 1.9077	51.5000 ± .4769
Sin., all.....	340	17.4483 ± .0298	10.3629 ± .0168	59.3412 ± .0857	9.2059 ± .0174	7.1383 ± .0142	77.5353 ± .1055	52.6588 ± .0689
Dex., plain <sup>1</sup> ...	1	17.4500	10.9000	61.5000	9.9000	7.9000	80.5000	55.5000
STANDARD DEVIATION.								
Sin., plain....	338	0.8156 ± .0211	0.4562 ± .0118	2.3483 ± .0609	0.4759 ± .0124	0.3862 ± .0100	2.8779 ± .0747	1.8836 ± .0489
banded..	2	.4500 ± .1517	.5000 ± .1686	1.0000 ± .3372	.4000 ± .1349	.6000 ± .2024	4.0000 ± 1.3454	1.0000 ± .3372
Sin., all.....	340	.8158 ± .0211	.4583 ± .0119	2.3423 ± .0606	.4771 ± .0123	.3893 ± .0100	2.8858 ± .0746	1.8847 ± .0487
Dex., plain....	1	.....	.....	.....	.....	.....	.....	.....

<sup>1</sup>Class values, hence discrepancy between per cent figure and observed.

In statistical characters the whole colony (table 81) shows still further reduction in the absolute measurements. The striped shells are even smaller than the plain reversed ones, and the differences are statistically significant in all of the seven standard characters, excepting only in the proportion of the aperture. The tooth (table 82) is less developed than in the Pohaitara colony.

TABLE 82.—*Partula otaheitana amabilis*, Ururoa Valley. Statistics of tooth development.

Series.	No.	None.	Trace.	Tooth.	Large.	Very large.	Mean value.	Standard deviation.
Sinistral plain.....	340	40	52	238	6	4	2.6530±.0276	0.7535±.0195
Sinistral, banded.....	3	1	1	1	..	..	2.0000±.3179	.8165±.2248
Sinistral, all.....	343	41	53	239	6	4	2.6473±.0275	.7565±.0194
Dextral, plain.....	1	..	..	1	..	..	3.0000	.....

The single dextral shell agrees sufficiently with the plain sinistral group to justify the belief that it is a product of a parent belonging to the latter; there are no grounds for regarding it as a migrant from another valley, for such sports do not seem to occur in Pohaitara, while a dry zone intervenes between Ururoa and Tuauru where the true dextral *affinis* exists.

Like the Pohaitara colony, this series displays a remarkably low degree of fertility, at least at the time of observation (table 83).

TABLE 83.—*Partula otaheitana amabilis*, Ururoa Valley. Fecundity.

Series.	Record.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.
Sinistral, plain.....	333	133	19.9	174	19	195	1.46	0.58
Sinistral, banded.....	3	2	66.6	2	0	2	1.00	0.66
Dextral, plain.....	1	0	0	...	..	...	....	....

Of 19 embryonic young borne by plain sinistral parents, all were sinistral, various shades of brown, and unbanded. The aberrant individuals, unfortunately, were barren of advanced embryonic contents.

#### GENERAL SUMMARY.

Having completed the detailed analysis of the primary variety *amabilis* as it exists in each of the four valleys of its range, we are in a position to treat it in a broader way so as to bring out more clearly its relation as a whole to the basic group, *P. otaheitana otaheitana* of Fautaua, and to compare the distinctive features of each of its four component colonies.

I. *The colony of each valley is distinguished by certain general peculiarities of its composition as a whole* (table 84). In Hamuta the large proportion of dextral individuals is a prominent differential characteristic. The Pirai colony is unique because of the large proportion of light-colored shells in its exclusively sinistral population. Pohaitara is inhabited by reversed snails only, but more than half of them are yellowish-red or "medium" in ground-color. In Ururoa the distinctive features are the preponderance of reddish-brown shells and the sporadic occurrence of banded sinistral snails as well as of plain dextral individuals. The uniform environmental conditions obtaining in the sector where these valleys lie can not be accountable for such diverse colonial characteristics as are manifested in the direction of the coil and in ground-color.

TABLE 84.—*Partula otaheitana amabilis* and *P. o. otaheitana*. Comparison by valleys, as to color-composition. (Color-classes in percentages of population, in each mode of coil.)

	Sinistral division.					Dextral division.				
	Plain.				Banded.	Plain.				Banded.
	Light I.	Yellowish II.	Reddish III.	Brownish IV.		Light I.	Yellowish II.	Reddish III.	Brownish IV.	
Fautaua.....	19.8	16.5	48.7	14.4	0.5	18.4	17.9	49.9	13.7	....
Hamuta.....	11.0	17.3	57.5	12.0	2.0	20.0	15.4	52.5	10.8	1.1
Pirai.....	71.8	24.8	1.3	0.1	1.9	....	....	....	....	....
Pohaitara.....	16.8		48.6	34.6	....	....	....	....	....	....
Ururoa.....	14.5		3.8	80.8	0.9	....	....	....	[1 shell]	....

It is interesting to note that the Hamuta and Pirai colonies form a couple that is somewhat more like the Fautaua colony than like the Pohaitara-Ururoa division; the latter resembles *affinis* of the territory further east, excepting in the matter of spirality. These circumstances deserve recognition, although it is not necessary to make a formal division of *amabilis* into western and eastern sections, with taxonomic names.

II. *The dimensional character of the four colonies varies, but the changes observed in passing through the range from west to east are not always consistently the same.* The facts presented in the earlier detailed descriptions are given in summary in tables 85 and 86, and graphically in table 87. In general, there is a decrease in *absolute* measures in passing from Fautaua to Hamuta, and on to Ururoa, and generally the differences are statistically significant. But the shell proportions in the Pirai-Pohaitara comparison show an increase, with a drop in the Pohaitara-Ururoa relation. The proportion of aperture length to shell length is also inconsistent. It is true that the shortening of the whole shell in passing from Pirai to Pohaitara is relatively greater than the reduction in other respects, whence the increase in proportionate measures; but it is difficult to see how this could be attributable to any influence of the environment which intensifies with further progress away from Fautaua. If this were so, then we should not have the decrease in the proportionate measure of the shell at the next geographical step.

III. *The dextral snails of any valley agree more closely with the reversed group of the same valley than with the dextral series of another valley, and the banded snails resemble their unbanded associates more than banded examples of a different valley.* The figures have been given in detail in the foregoing description, and nothing remains to be added. The data of heredity prove the real inter-relationships of the different color-classes and of the two types of direct and reversed shells, wherever those occur in the same colony.

IV. *Combining the four colonies, the variety amabilis taken as a whole may be compared with otaheitana and may be defined for future comparison with other primary varieties.* It is unnecessary to deal with the color characters anew. The statistical data may be summarized in two ways, with two different aims. In the first instance

we may combine the four colonies and take into account all of the members of each association, thus weighting them according to the actual collections, while in the second case we may average the determinations for each character, weighting all four colonies equally. For obvious reasons the dextral components must be omitted. The figures are given in table 88.

TABLE 85.—*Partula otaheitana otaheitana* and *P. o. amabilis*. Comparison of statistical characters.

MEAN VALUE.									
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index. <sup>1</sup>
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
		<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>mm.</i>	<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	
Fautaua, s....	509	19.1003±.0268	10.9888±.0142	57.4373±.0719	9.8321±.0142	7.7239±.0115	78.4744±.0818	51.4076±.0590	2.7138±.0267
Hamuta, s....	289	18.3282±.0332	10.7097±.0172	58.4100±.0928	9.5617±.0190	7.4979±.0160	78.2301±.1125	52.0467±.0785	3.0903±.0276
Pirai, s.....	939	18.2797±.0222	10.6657±.0111	58.2998±.0528	9.4632±.0117	7.3718±.0097	77.8983±.0621	51.6927±.0405	2.8966±.0177
Pohaitara, s...	379	17.5608±.0273	10.4836±.0156	59.6187±.0683	9.2588±.0144	7.1945±.0130	77.6847±.0984	52.5871±.0639	2.6357±.0288
Ururoa, s....	340	17.4483±.0298	10.3629±.0168	59.3412±.0857	9.2059±.0174	7.1383±.0142	77.5353±.1055	52.6588±.0689	2.6473±.0275
Fautaua, d....	421	19.3184±.0304	10.9736±.0172	56.7447±.0745	9.8853±.0163	7.6667±.0130	77.4976±.0937	51.1176±.0644	2.7600±.0289
Hamuta, d....	166	18.5018±.0475	10.7844±.0262	58.1988±.1118	9.6506±.0284	7.5386±.0216	78.0361±.1479	52.1144±.0929	3.0000±.0377
Ururoa, d....	1	17.45	10.90	61.50	9.90	7.90	80.50	55.50	3.0
STANDARD DEVIATION.									
Fautaua, s....	509	0.8961±.0189	0.4768±.0100	2.4049±.0508	0.4769±.0100	0.3845±.0081	2.7369±.0579	1.9737±.0417	0.9069±.0189
Hamuta, s....	289	.8359±.0235	.4396±.0122	2.3409±.0656	.4833±.0134	.4080±.0113	2.8388±.0795	1.9788±.0555	.7096±.0195
Pirai, s.....	939	1.0096±.0157	.5047±.0078	2.3977±.0373	.5317±.0083	.4324±.0069	2.8229±.0439	1.8391±.0286	.7772±.0125
Pohaitara, s...	379	.7885±.0193	.4508±.0110	1.9720±.0483	.4164±.0102	.3738±.0092	2.8401±.0696	1.8435±.0452	.8408±.0203
Ururoa, s....	340	.8158±.0211	.4583±.0119	2.3423±.0606	.4771±.0123	.3893±.0100	2.8858±.0746	1.8847±.0487	.7565±.0194
Fautaua, d....	421	.9263±.0215	.5219±.0122	2.2660±.0527	.4969±.0115	.3943±.0092	2.8505±.0663	1.9595±.0455	.8880±.0204
Hamuta, d....	166	.9070±.0336	.5000±.0185	2.1353±.0790	.5433±.0201	.4130±.0152	2.8594±.1058	1.7756±.0657	.7407±.0266
Ururoa, d....	1	.....	.....	.....	.....	.....	.....	.....	.....

<sup>1</sup>The numbers of individuals are greater in the cases of tooth determinations.

TABLE 86.—*Partula otaheitana otaheitana* and *P. o. amabilis*. Progressive comparison from valley to valley. Differences in mean value.

	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index.
	Length.	Width.	Proportions.	Length.	Width.	Proportions.		
Fautaua, s....	<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>p. ct.</i>	
Hamuta, s....	−0.6721±.0426	−0.2791±.0223	+0.9727±.1130	−0.2704±.0237	−0.2260±.0197	[−0.2443±.1391]	+0.6381±.0982	+0.3765±.0384
Pirai, s.....	[−.0485±.0399]	−.0440±.0204	[−.1102±.1067]	−.0985±.0223	−.1261±.0187	−.3318±.1285	−.3540±.0883	−.2937±.0328
Pohaitara, s...	−.7189±.0351	−.1821±.0191	+1.3189±.0863	−.2044±.0185	−.1773±.0162	[−.2136±.1163]	+ .8944±.0756	−.2601±.0338
Ururoa, s....	−.1125±.0404	−.1207±.0229	−.2775±.1096	−.0529±.0226	−.0562±.0192	[−.1494±.1442]	[+ .0717±.0939]	[+ .0116±.0398]
Fautaua, d....	−0.8166±.0564	−.1892±.0313	+1.4541±.1343	−.2347±.0327	−.1281±.0252	+ .5385±.1766	+ .9968±.1130	+ .2400±.0475
Hamuta, d....								

If the period of collection had been exactly the same for all four valleys, and the conditions of moisture also had been identical, then the characters of the variety as a whole, as in the first case, would best be defined by the figures for all individuals taken together in one series; certainly the variety is actually more abundant in Pirai than in Hamuta, and greater weight should be granted accordingly to the

TABLE 87. *Partula otaheitana otaheitana* (Fautaua Valley) and *Partula otaheitana amabilis* (Hamuta to Ururoa Valleys). Progressive variation of the colonies in range and mean value. (Sinistral, full lines; dextral, interrupted lines.)

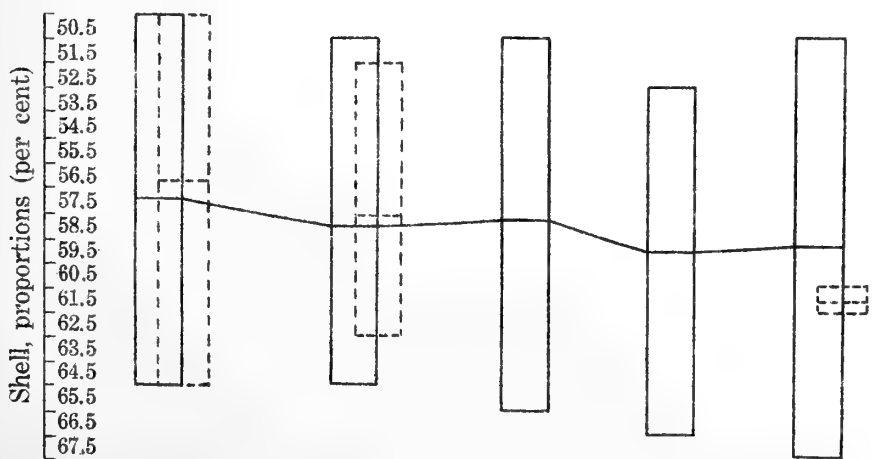
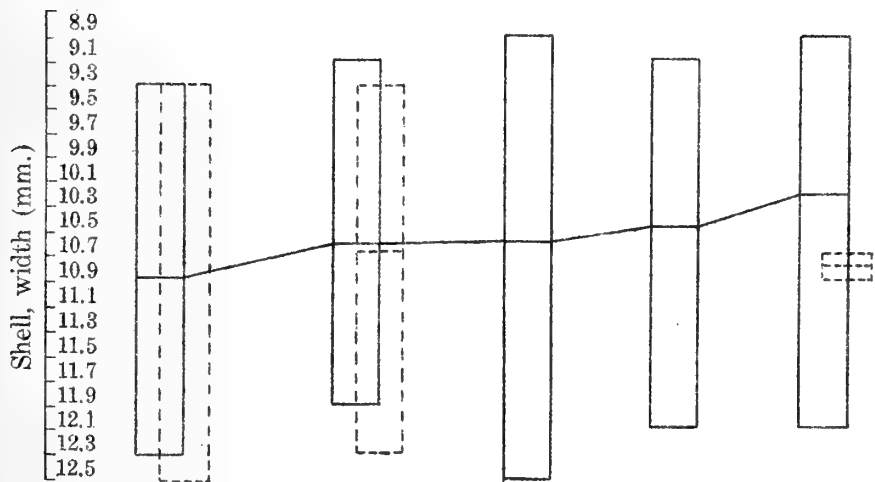
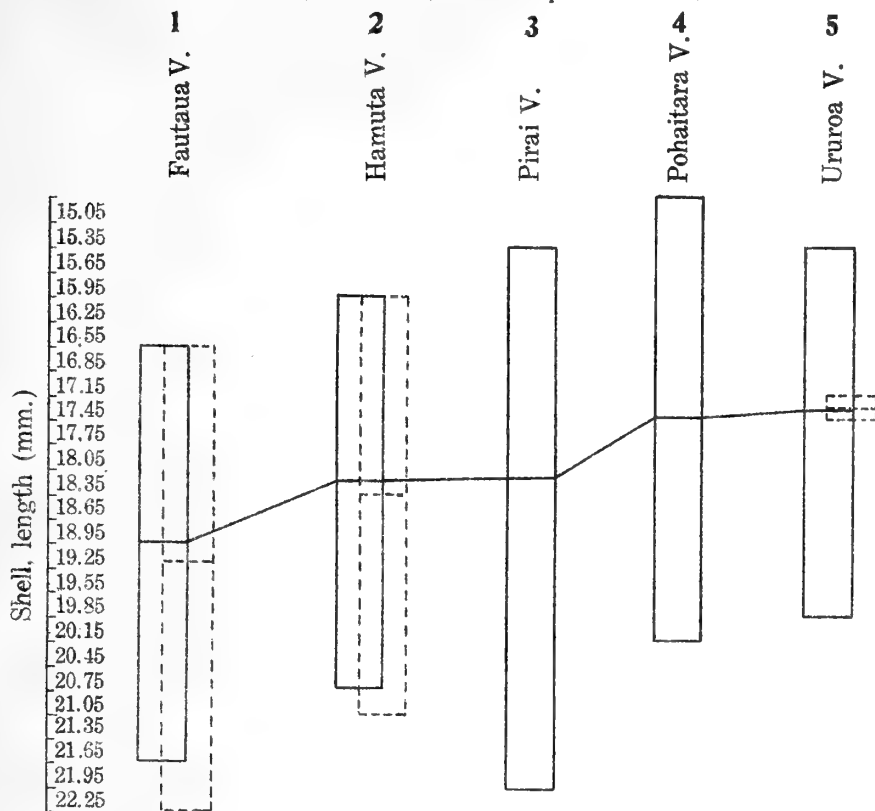
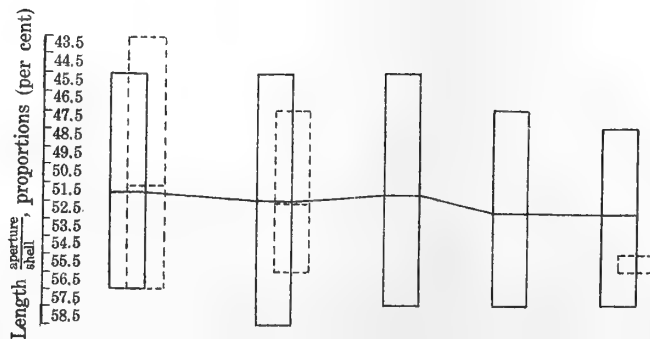
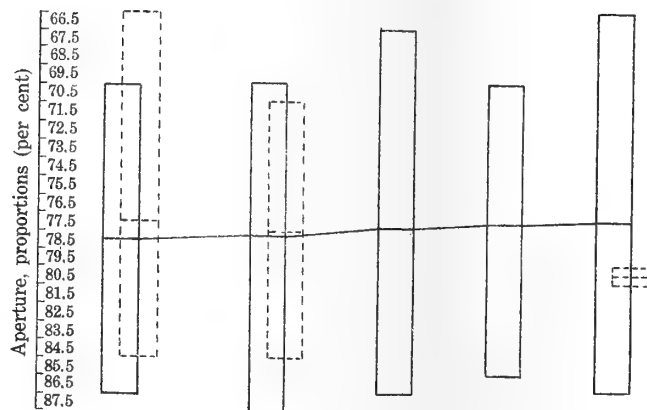
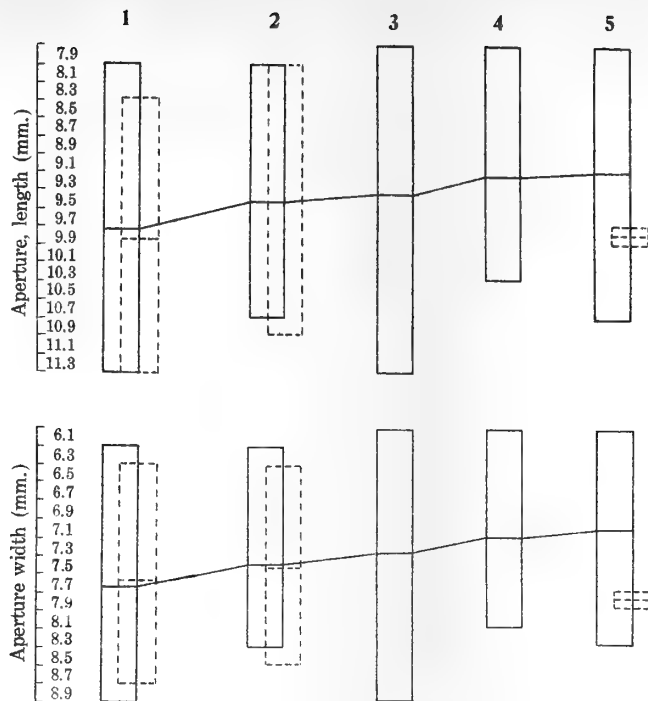
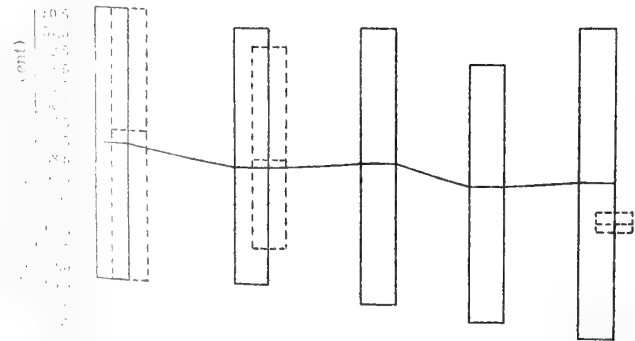
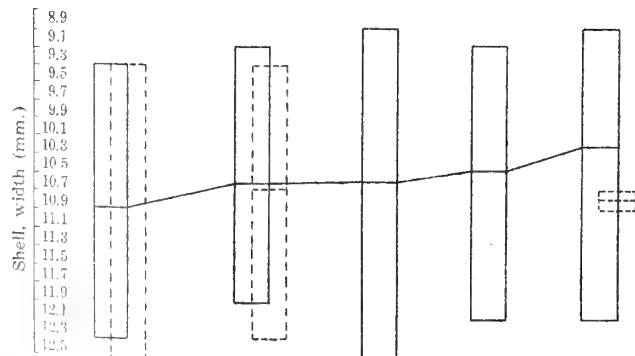
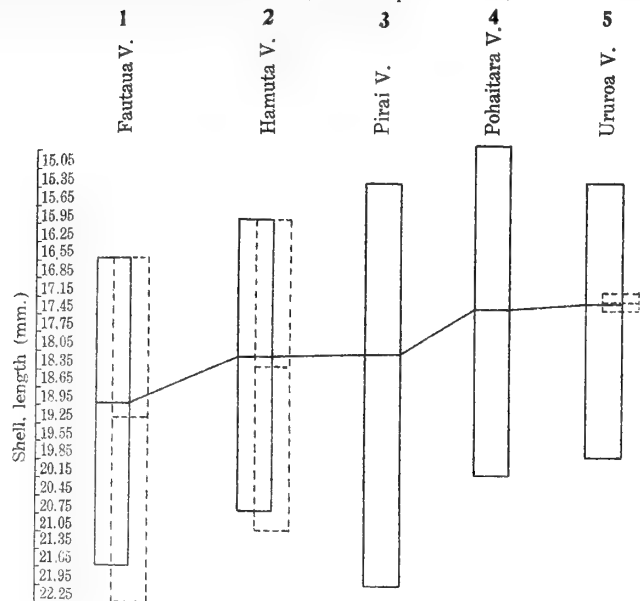






TABLE 87. *Partula otaheitana otaheitana* (Fautaua Valley) and *Partula otaheitana amabilis* (Hamuta to Ururoa Valleys). Progressive variation of the colonies in range and mean value. (Sinistral, full lines; dextral, interrupted lines.)





Pirai association. However, because the times of collection could not be made equal in length and because also the meteorological conditions differed, the figures are approximate, even if not final, descriptions of the abundance of *amabilis* as it exists in the sector of its range. The second or averaged figure for each character has a biological significance of another kind, because each valley colony constitutes a complex with its own hereditary qualities; the general average of the four valley types recognizes an equal value of these types, irrespective of the abundance or paucity of its representatives in any one case. Both modes of viewing the summarized facts will be important in our final summary.

TABLE 88.—*Partula otaheitana otaheitana* and *P. o. amabilis*. Statistical comparison.

Character.	Mean value.			Standard deviation.		
	<i>P. otaheitana</i> <i>otaheitana</i> .	<i>P. o. amabilis</i> combined.	<i>P. o. amabilis</i> average of valley types.	<i>P. otaheitana</i> <i>otaheitana</i> .	<i>P. o. amabilis</i> combined.	<i>P. o. amabilis</i> average of valley types.
Shell length, mm.....	19.1003±.0208	18.0018±.0151	17.9042	0.8961±.0189	0.9885±.0107	0.8624
width, mm.....	10.9888±.0142	10.5839±.0076	10.5555	.4768±.0100	.4952±.0054	.4633
proportions, p. ct....	57.4373±.0719	58.7547±.0368	58.9174	2.4049±.0508	2.4085±.0260	2.2632
Aperture length, mm.....	9.8321±.0142	9.3931±.0078	9.3724	.4769±.0100	.5107±.0055	.4771
width, mm.....	7.7239±.0115	7.3152±.0065	7.3006	.3845±.0081	.4282±.0046	.4009
proportions, p. ct....	78.4744±.0818	77.8426±.0435	77.8371	2.7369±.0579	2.8482±.0306	2.8469
Length aperture ÷ length shell, proportions, p. ct....	51.4076±.0590	52.0881±.0293	52.2466	1.9737±.0417	1.9171±.0207	1.8865
Tooth, index.....	2.7138±.0267	2.8292±.0122	2.8175	.9069±.0189	.7936±.0086	.7710

*P. o. otaheitana* (sinistral), *n* = 509 (tooth 524).*P. o. amabilis* (sinistral), *n* = 1947 (tooth 1909).

## PARTULA OTAHEITANA RUBESCENS Reeve.

## GENERAL CONSIDERATIONS.

Beyond the range of the primary variety just described, the territory beginning with the valley of Tuauru is inhabited by two distinct subdivisions of *P. otaheitana*. One of these comprises the large sinistral forms of considerable beauty that were described under the name of *Partula rubescens* by Reeve in 1850; to this same variety must be referred the shells distinguished and distributed by Pease as *Partula turricula*. The other variety, *Partula otaheitana affinis*, accompanies *rubescens* in nearly, but not quite, all of its valleys throughout the eastern part of Tahiti nui and Taiarapu as far as Apirimaue, in the southeastern district of Papeari.

Such being the general situation, the problem dealing with the factorial value of the environment may be attacked with more confidence than heretofore, inasmuch as two entirely distinct groups of variants exist *under identical conditions in the same valleys*; they do not interbreed, as the ample evidence attests, and neither of them can be regarded as ancestral to the other, but each is derivable from a basic complex similar to *P. otaheitana otaheitana* as it exists in Fautau Valley at the present time. Therefore the relations of these two series—*rubescens* and *affinis*—are essentially different from those obtaining between the light and dark, the plain and colored, or the direct and reversed snails that constitute an *amabilis* colony such as the associ-

ation in Hamuta Valley, although each of them by itself is composed of subordinate types which do display genetic and morphological relationships similar to those of the components which constitute a single *amabilis* association. For practical purposes, it is clearly necessary to take up *rubescens* by itself and to pass over the *affinis* division for the time; the parallel consideration of both of these sections, in geographical sequence, would lead to great confusion.

Reeve's description of *rubescens* is as follows:

"Shell acuminate oblong, rather thick, sinistral, compressly umbilicated; whorls 6, smooth, somewhat rounded, lip and columella broadly reflected. Pink, red-brown towards the apex."

Garrett presents the following significant statement concerning this form and its distribution:

"Reeve's *rubescens*=*turricula* is abundant in Papinoo,<sup>1</sup> and occurs sparingly in all the valleys as far as the southeast end of the island. Like *amabilis* "it can not be separated from the sinistral turreted *otaheitana* inhabiting Fautaua. It is always sinistral, never banded, and, though usually of a reddish tint, is frequently straw-yellow or fulvous, with or without a reddish or pinky apex. Though described as edentate, some have a small parietal tooth. Reeve gave no locality, and Pfeiffer erroneously cited the Marquesas as its habitat."

In the collections of some museums, strikingly banded specimens of *sinistrorsa* have been included in representative series of *rubescens*; really they are entirely different and belong to a distinct primary variety. The matter of the columella tooth is important, for, as Garrett states, some specimens possess this structure, *but only in the colonies of certain valleys*; ordinarily the shells are utterly edentate.

While the major characters as given in the above citations from Reeve and Garrett are repeated with substantial faithfulness in all of the valleys where *rubescens* occurs, marked differences in the make-up of the colonies appear on even a cursory examination. In some instances the light yellow shells preponderate, while in others the reddish members exceed them in number; sometimes a smaller or larger average size constitutes the colonial character. In other cases, a unique feature like the pillar tooth already mentioned, or a very unusual kind of bicolored marking, appears as a distinctive peculiarity of the shells of a single valley association.

A general description of *rubescens* as a whole, covering all of the varied colonies of Tahiti, enumerates characters which are identical with some and with some only of those exhibited by *P. o. otaheitana*, the parent stock as it exists in Fautaua Valley; the other unit qualities do not appear. In comparison with the list and the combinations as given in the general description of the species, *rubescens* displays the following features:

*Coil*: sinistral always, dextral lacking.

*Size*: large, with only one or two exceptional mutants.

*Ground color*: yellowish, reddish, or rarely intermediate between these; never brown or strigated. Never banded.

*Apex*: may or may not be deeply tinged, varying in percentage in different valleys.

*Surface*: very smooth and shiny, never closely corrugated.

<sup>1</sup>Misspelled throughout Garrett's memoir.

In brief, *rubescens* as a primary variety seems to have been derived from a complex basic stock like that still existing in Fautaua Valley, through an elimination or dropping out of certain qualities represented in the original heritage.

The absolute and relative members of *P. o. rubescens* in the valleys of its occurrence have been given in table 56. A further analysis of the material (table 89) presents the numerical relations of the principal color-classes in each and every valley. All of these colonies will be discussed in the summary at the end of this section; in describing them in detail, only the larger collections will be analyzed, and little attention will be given to valleys like Faaripoo, Mahaena, and Tehoro, where one or only a few shells of this variety were taken.

TABLE 89.—*Partula otaheitana rubescens*. Numerical relation of the principal color-types.

	Total No. of adults.	Yellow class.	Reddish class.		Total No. of adults.	Yellow class.	Reddish class.
Tuauru.....	8	2	6	Utuufai.....	5	...	...
Ahonu.....	146	79	67	Faone.....	2	1	...
Faaripoo.....	2	1	1	Tehoro.....	1	...	...
Papenoo.....	342	105	237	Haavini.....	214	<sup>2</sup> 207	7
Farapa.....	0	...	...	Tautira.....	82	<sup>3</sup> 76	6
Faarumai.....	19	...	...	Aionifaa.....	1	...	...
Tiarei.....	15	11	4	Aiurua.....	119	<sup>4</sup> 101	18
Mahaena.....	6	...	6	Oopu.....	272	<sup>5</sup> 126	<sup>5</sup> 146
Paraura.....	89	67	22	Apirimaue.....	1	...	1
Faatautia.....	0	...	...		1,436	...	...
Papeiha.....	112	171	41				

<sup>1</sup>Whitish 10, yellowish 61.

<sup>2</sup>Yellow, clear apex 54; yellow, red apex 153.

<sup>3</sup>Yellow, 23; orange, 53.

<sup>4</sup>Yellow, clear apex, 81; yellow, red apex, 20.

<sup>5</sup>See detailed description.

That there should be such striking variations in the absolute frequency of this form is a fact which should not be passed over as insignificant; it is the same fact, with an identical meaning, that was discussed at some length in the section dealing with *Partula hyalina*. No claim is made that the figures given for the several valleys are absolutely exact indications of the real frequencies of *rubescens*, for larger series would undoubtedly show differences. Yet, so far as they go, they have an approximate if not a final value for the problem dealing with environmental influence. In a word, the marked change in the prevalence of *rubescens*, in passing from Papenoo to Farapa and Faarumai, or from Papeiha to Utuufai, must be interpreted as indicating a real constitutional difference in colonial vigor, on a plane with congenital variations in respect to size and shape and color. Beyond the limits set by environmental conditions to the existence of any snail-life whatsoever, external circumstances do not seem to cause variations in numerical abundance.

#### TUAURU AND AHONU VALLEYS.

The shells of Tuauru are only few in number, but they are interesting as being the first-found *rubescens* beyond the range of *amabilis*. In correspondence with this juxtaposition, they display qualities that are transitional from *amabilis* to the larger and more characteristic *rubescens* of Ahonu Valley, which occur in greater relative abundance. Three examples of the Tuauru series are given in plate 26, figs. 51 to 53. The colors are duller than in the valley beyond, and the absolute

measures are much less (see table 90); the tooth appears as a trace in only one of the eight specimens. The statistics of fecundity and of the heredity of ground-color are naturally few (table 90), but the latter are valuable as indicating that the two color-classes interbreed, or, at least, that they are not absolutely separated and independent.

TABLE 90.—*Partula otaheitana rubescens*, Tuauru Valley.

STATISTICAL DESCRIPTION.			
Character.	Class range.	Mean value.	Standard deviation.
Shell length, mm.....	18.25-20.25	19.5000±.1333	0.5590±.0942
width, mm.....	10.15-11.15	10.5500±.0884	.3708±.0625
proportions, per cent.....	51.5-56.5	54.0000±.4130	1.7320±.2920
Aperture length, mm.....	9.1-10.1	9.7000±.0754	.3162±.0533
width, mm.....	6.9-7.5	7.2250±.0473	.1984±.0334
proportions, per cent.....	71.5-78.5	75.1250±.4608	1.9324±.3258
Length aperture ÷ length shell, proportions, per cent.....	47.5-51.5	49.3750±.4034	1.6918±.2852
Tooth, index.....	1-2	1.1250±.0789	.3318±.0558

FECUNDITY (6 RECORDS).		HEREDITY.			
			Young, yellow.	Young, red.	Total.
Gravid.....	4	Adults:			
Gravid, per cent.....	66.6	Yellow.....	..	1	1
		Reddish.....	4	2	6
Eggs.....	2	Total.....	4	3	7
Young.....	7				
Average for gravid.....	2.25				
Average for all.....	1.50				

The adult specimens from Ahonu amount to 146, or 49.4 per cent of the whole full-grown *otaheitana* population. They are readily separated into the two principal color-classes, of which the yellow predominates. Of the examples figured belonging to the yellow class (plate 26, figs. 54 to 57), one illustrates the result of decortication (fig. 54); in the case of the red class (plate 26, figs. 58 to 63), decortication changes the color to a pinkish tinge (plate 26, fig. 58). The examples show at a glance that the shells of this colony are larger than those of Tuauru, and also that the second color-type displays a clearer red.

The colonial statistics (table 91) are sufficient to give a basis for a full comparison of the two classes. It appears that the yellow shells are larger than the red ones, to a significant degree in shell length, aperture length, and perhaps in the width of the aperture; there are also significant differences in the proportions of the shell as a whole and of the aperture. In brief, the red shells, in general, are smaller and more closely coiled—a fact to be borne in mind when similar classes of the succeeding valleys are compared in detail.

The pillar tooth is remarkably developed in this colony; only in Papenoo is it exceeded (table 92).

TABLE 91.—*Partula otaheitana rubescens*, Ahonu Valley. Statistical analysis.

Character.	Mean.			Difference between yellow and red.	Standard deviation.		
	All (145).	Yellow (78).	Red (67).		All.	Yellow.	Red.
Shell:							
length, mm. ....	20.6603 ± .0513	20.8969 ± .0705	20.4664 ± .0783	+0.4305 ± .1054	0.9517 ± .0377	0.9236 ± .0498	0.9472 ± .0554
width, mm. ....	11.3166 ± .0296	11.3487 ± .0431	11.2791 ± .0398	+0.0696 ± .0586	.5291 ± .0209	.5640 ± .0305	.4827 ± .0281
proportions, p. ct. . .	54.6379 ± .1295	54.3462 ± .1703	54.9776 ± .1903	-.6314 ± .2553	2.3126 ± .0916	2.2308 ± .1204	2.3585 ± .1346
Aperture:							
length, mm. ....	10.2766 ± .0286	10.3564 ± .0392	10.1836 ± .0405	+0.1728 ± .0563	.5106 ± .0202	.5133 ± .0277	.4913 ± .0286
width, mm. ....	7.7662 ± .0236	7.7975 ± .0347	7.7299 ± .0310	+0.0676 ± .0465	.4215 ± .0167	.4549 ± .0245	.3758 ± .0219
proportions, p. ct. . .	75.4379 ± .1540	75.1282 ± .2308	75.7988 ± .1907	-.6706 ± .2994	2.7498 ± .1098	3.0217 ± .1632	2.3437 ± .1348
Length aperture ÷ length shell, proportions, p. ct. ....	49.6586 ± .1016	49.6539 ± .1294	49.6642 ± .1602	-.0103 ± .2059	1.8144 ± .0718	1.6952 ± .0914	1.9439 ± .1133

TABLE 92.—*Partula otaheitana rubescens*, Ahonu Valley.

TOOTH.								
Group.	No.	None. (1)	Trace. (2)	Tooth. (3)	Large. (4)	Very large. (5)	Mean value.	Standard deviation.
Yellow.....	79	17	28	19	8	7	2.4937 ± .0903	1.1893 ± .0638
Reddish.....	67	30	17	12	4	4	2.0299 ± .1235	1.4997 ± .0873
All.....	146	47	45	31	12	11	2.2809 ± .0675	1.2092 ± .0477

FECUNDITY.									HEREDITY.			
	Records.	No. of gravid.	Per cent gravid,	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.		Young, yellow.	Young, red.	Total
Adults:									Adults:			
Yellow..	69	35	50.7	17	37	54	1.54	0.78	Yellow..	31	6	37
Reddish.	58	28	48.3	9	30	39	1.39	0.67	Reddish.	6	24	30
All. . .	127	63	49.6	26	67	93	1.47	0.73	All . . . .	37	30	67

In spite of the low degree of fecundity (table 92), at least at the time of collection, the statistics of heredity (table 92) are of much interest. Each class produces its own kind in the larger number of instances, but young of the contrasted color also appear. Cases occur among both kinds of adults where two embryonic snails differ from one another; in other instances the young may be all alike, but all different from their parent in the ground-color. It is a remarkable coincidence that the numbers of red and yellow embryonic snails correspond exactly with the numbers of gravid yellow and red adults. Scanty as the data may be, the colony seems to be stable as far as relative numbers of its two component classes are concerned.

#### PAPENOO VALLEY.

Passing by Faaripoo Valley, which yielded only two living adult *rubescens* in a total collection of 313, we reach the great valley of Papenoo (plates 9, 10, and 11). In a geographical and topographical sense, this constitutes the largest area that is continuously habitable for Partulæ. It comprises the extensive and almost circular

crater basin in the exact center of Tahiti nui, which is bounded by more or less lofty ridges, raised here and there to high mountain peaks. Outward from this depression, and almost northward in general trend, the drainage area slopes gradually toward the coast and narrows so greatly as to be little wider than Fautaua and many valleys of the south, until it debouches upon the coastal plain.

At its mouth Papenoo Valley is very broad and dry, and its limiting buttresses are also somewhat arid and therefore devoid of tall vegetation. About a mile inland the high sides draw together and the stream runs swifter and deeper, with many stony islands in its bed. On the level flood-plain, dry ferns, guava trees, and hibiscus form a characteristic plant association. Further on, where the slopes are higher and steeper, larger trees, turmeric, and succulent plants like *Dracæna* are established, but no snails are to be found until a point nearly 2 miles from the coast is reached, at a barometric height of 75 feet. This is a low level for *Partulæ*, but the conditions of moisture and vegetation are such as to render the region habitable at a much lower point than in other large valleys, like Fautaua and Tipaerui. In the succeeding zone, further inland, the trees and shrubs grow still more thickly, and among them are the plantains, vines, and *Pandanus* that constitute the customary association for the harboring of *Partulæ*, which there occur in some abundance. The steep accessory gullies entering the main valley from the sides are especially favorable for the collection of snails.

In conducting the present research it was impracticable to make the journey throughout the whole length of Papenoo Valley, and to cross over the boundary ridges into Fautaua or into Vaihiria. Collections of snails were personally obtained in 1906, 1908, and 1909; and as in the case of Pirai Valley, they were taken in different but nearly contiguous parts of the valley. In the first year, on account of the effects of the cyclone and the difficulty of penetration, only the lowermost periphery of the inhabited area was investigated up to a point about 3 miles from the coast; in 1908, snails were obtained from  $3\frac{1}{2}$  to  $4\frac{1}{2}$  miles up the valley, while in 1909 the area of collection extended to about  $5\frac{1}{2}$  miles inland. While it would be extremely interesting to investigate the wide circular basin in the center of Tahiti nui, the task would demand so great an expenditure of time and energy as to interfere seriously with the exploration of the peripheral parts of the island, and for this reason it was not attempted. It will be borne in mind, therefore, that the following description of the snails of Papenoo Valley includes only the positive results established for the drainage area which parallels Ahonu and Tuauru Valleys.

The two color-classes are as well distinguished as heretofore. Among the yellow shells (plate 27, figs. 1 to 4) are some that are almost pure white (fig. 1) as the result of decortication. In the red class (plate 27, figs. 5 to 11) the tones vary somewhat, according to the strength or weakness of the distinctive color; a pink coloration results from the wearing away of the epidermis (plate 27, fig. 8). The rich tints upon the lips and within the cavity of the last whorl, although they are not always developed, add much to the beauty of the shells of this division. A single diminutive example was found here (plate 27, fig. 11).



The relative numbers of yellow and red snails are different for the three successive areas of collection (table 93). While the figures for 1906 and 1908—outer and intermediate areas—are not very diverse and refer to few individuals, yet their comparison with the numbers for 1909—inner area—shows that the red group undoubtedly diminishes in relative abundance in passing inland.

TABLE 93.—*Partula otaheitana rubescens*, Papenoo Valley. Class frequencies.

Area.	Year.	No. of adults.	No. of yellow.	No. of red.	Per cent of yellow.	Per cent of red.
Lower valley.....	1906	70	19	51	27.14	72.85
Middle valley.....	1908	90	21	69	23.33	76.66
Upper valley.....	1909	182	65	117	35.71	64.28
Whole area.....	....	342	105	237	30.70	69.29

Comparing the three annual series as wholes—i. e., the yellow and red shells taken together—the coastward shells of 1906 differ distinctly from the intermediate series in absolute measures, and significantly so; in proportionate measures they are the same, allowing for the scope of the probable errors involved (table 94). The inner series of 1909 differs from the intermediate group, it is true, but only in shell proportions, and perhaps in the pillar tooth, does the divergence approach a significant figure. Like *P. otaheitana amabilis* and *P. filosa* of Pirai Valley, *P. o. rubescens* of this region exhibits a reduction in size when snails of the interior are contrasted with those of the extreme outer edge of the inhabited area. Again it would seem that the logical reason for the facts is to be found in a more rigid elimination where conditions are less favorable, as in the lower dry part of the valley, where only the larger and more vigorous individuals can subsist.

TABLE 94.—*Partula otaheitana rubescens*, Papenoo Valley. Comparison of annual series.

MEAN VALUE.									
	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
		mm.	mm.	p. ct.	mm.	mm.	p. ct.	p. ct.	
1906	70	20.5785 ± .0726	11.3915 ± .0495	55.1572 ± .2071	10.4771 ± .0432	7.8315 ± .0407	74.6572 ± .2444	50.7571 ± .1722	2.8286 ± .0770
1908	86	20.3430 ± .0694	11.2186 ± .0425	55.1163 ± .1464	10.2675 ± .0385	7.6465 ± .0335	74.3721 ± .1917	50.5349 ± .1351	2.2889 ± .0744
1909	180	20.3139 ± .0453	11.3078 ± .0263	55.5723 ± .1203	10.2989 ± .0259	7.6734 ± .0215	74.5500 ± .1582	50.6889 ± .0952	2.4651 ± .0495
All	336	20.3765 ± .0340	11.3024 ± .0207	55.3690 ± .0865	10.3280 ± .0195	7.6994 ± .0168	74.5268 ± .1104	50.6637 ± .0714	2.4828 ± .0371
Dif.									
1906-1908		-.2355 ± .1004	-.1729 ± .0652	[-.0409 ± .2536]	-.2096 ± .0578	-.1850 ± .0527	[-.2850 ± .3106]	[-.2222 ± .2189]	-.5397 ± .1070
Dif.									
1908-1909		[-.0291 ± .0828]	[+.0892 ± .0499]	+.4560 ± .1895	[+.0314 ± .0464]	[+.0269 ± .0398]	[+.1779 ± .2505]	[+.1540 ± .1652]	[+.1762 ± .0893]
STANDARD DEVIATION.									
1906	70	0.9004 ± .0513	0.6138 ± .0350	2.5684 ± .1464	0.5362 ± .0305	0.5052 ± .0288	3.0314 ± .1728	2.1360 ± .1218	0.9557 ± .0544
1908	86	.9539 ± .0491	.5846 ± .0300	2.0125 ± .1035	.5378 ± .0272	.4610 ± .0237	2.6360 ± .1355	1.8580 ± .0950	1.0461 ± .0526
1909	180	.9002 ± .0320	.5242 ± .0186	2.3922 ± .0851	.5157 ± .0183	.4281 ± .0152	3.1469 ± .1119	1.8936 ± .0643	.9971 ± .0350
All	336	.9246 ± .0240	.5627 ± .0146	2.3504 ± .0612	.5314 ± .0138	.4555 ± .0119	3.0013 ± .0781	1.9395 ± .0505	1.0172 ± .0262

The next question to present itself deals with the possible differentiation of the red and yellow shells in structural respects. As the relative numbers of these two classes are not the same in the three series compared above, it might be that the divergence of one subcolony from another in average qualities is due to a real difference in the case of yellow shells, while the red ones remain the same. Do the red and yellow classes really differ, and does each kind change as the observer progresses inland?

TABLE 95.—*Partula otaheitana rubescens*, Papenoo Valley. Comparison of color-classes on the basis of mean values.

Character.	SERIES OF 1906		
	Yellow (19).	Red (51).	Difference, yellow as compared with red.
Shell length, mm.....	20.4342 ± .1237	20.6323 ± .0900	[−0.1981 ± .1562]
width, mm.....	11.1737 ± .0635	11.4726 ± .0533	− .2989 ± .0829
proportions, p. ct.....	54.3421 ± .4178	55.4608 ± .2313	−1.1187 ± .4775
Aperture length, mm.....	10.2790 ± .0941	10.5509 ± .0459	− .2719 ± .1047
width, mm.....	7.7211 ± .0934	7.8687 ± .0410	[− .1476 ± .1020]
proportions, p. ct.....	74.8684 ± .3696	74.5785 ± .3055	[+ .2899 ± .4795]
Length aperture ÷ length shell, proportions, p. ct. ....	50.1316 ± .3592	50.9902 ± .1901	− .8586 ± .4064
Tooth, index.....	2.7895 ± .1186	2.8431 ± .0960	[− .0536 ± .1525]
Character.	SERIES OF 1908		
	Yellow (21).	Red (65).	Difference, yellow as compared with red.
Shell length, mm.....	20.2976 ± .1772	20.3577 ± .0717	[−0.0601 ± .1911]
width, mm.....	11.0619 ± .0790	11.2693 ± .0494	− .2074 ± .0931
proportions, p. ct.....	54.5952 ± .3241	55.2846 ± .1604	[− .6894 ± .3616]
Aperture length, mm.....	10.1572 ± .0648	10.3031 ± .0466	[− .1459 ± .0797]
width, mm.....	7.5857 ± .0571	7.6662 ± .0402	[− .0805 ± .0698]
proportions, p. ct.....	74.5000 ± .3548	74.3308 ± .2262	[+ .1692 ± .3548]
Length aperture ÷ length shell, proportions, p. ct. ....	50.2143 ± .2805	50.6384 ± .1431	[− .4241 ± .3149]
Tooth, index.....	2.2857 ± .1516	2.2899 ± .0853 (69)	[− .0042 ± .1739]
Character.	SERIES OF 1909		
	Yellow (65).	Red (115).	Difference, yellow as compared with red.
Shell length, mm.....	20.3423 ± .0736	20.2978 ± .0575	[+0.0445 ± .0934]
width, mm.....	11.4108 ± .0451	11.2496 ± .0318	+ .1612 ± .0551
proportions, p. ct.....	56.1462 ± .2163	55.2478 ± .1390	+ .8984 ± .2571
Aperture length, mm.....	10.3523 ± .0443	10.2687 ± .0317	[+ .0836 ± .0544]
width, mm.....	7.6816 ± .0335	7.6687 ± .0270	+ .0129 ± .0430
proportions, p. ct.....	74.2231 ± .2680	74.7448 ± .1949	[− .5217 ± .3314]
Length aperture ÷ length shell, proportions, p. ct. ....	50.9151 ± .1587	50.5608 ± .1182	[+ .3543 ± .1979]
Tooth, index.....	2.4000 ± .0787 (65)	2.4701 ± .0640 (117)	[− .0701 ± .1014]

The detailed facts (table 95) give affirmative answers to both questions, but in the second case a qualification is necessary; both classes change, but to diverse degrees. In the 1906 series, the yellow shells are collectively smaller than the red ones in all four absolute measures, in two of which they are certainly different; and they are narrower in shell proportions. Exactly similar relations obtain in the 1908 series, although the differences are not so large as compared with their probable errors, except in one case. But the 1909 series shows no such relation; indeed, in two or three characters it is entirely reversed. The facts may be stated in another way: the yellow shells of successive years—and localities—at first become smaller (1906–1908), and then larger (1908–1909), but the red shells become smaller with some significance in both cases; because the yellow shells are more abundant relatively in the last year's collection—inner locality—their increase in size in the second step—1908 to 1909—masks the change in the red type when the figures for the combined classes are compared, as in table 94. In a word, the reduction in size of the whole series of 1909 can not be attributed to a greater proportion of small red individuals. Thus the more detailed analysis of the color-classes brings to light most important relations which otherwise would have been undisclosed.

TABLE 96.—*Partula otaheitana rubescens*, Papenoo Valley.

STATISTICS OF FECUNDITY.								
Series.	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.
1906.....	49	24	48.9	19	15	34	1.41	0.69
1908.....	89	75	84.2	106	119	225	3.00	2.52
1909.....	173	157	90.7	327	174	501	3.19	2.89
	311	256	....	452	308	760	....	....
COMPARATIVE FECUNDITY: YELLOW AND RED.								
				No. of gravid.	Total contents.	Total young.	Average contents.	Average young.
Yellow, 1906.....				9	13	4	1.4	0.4
1908.....				17	49	22	2.9	1.3
1909.....				63	200	66	3.1	1.5
Yellow, all.....				89	262	92	2.9	1.0
Red, 1906.....				15	21	11	1.4	0.7
1908.....				58	176	97	3.0	1.7
1909.....				94	301	108	3.2	1.1
Red, all.....				167	498	216	2.9	1.3

In fecundity, the first series is very low (table 96), while those of 1908 and 1909 agree in a relatively high rate. The first series was taken during the early part of the year, and the other was secured during the middle months. Apparently the hotter and wetter season witnesses the initiation of renewed reproductive activity.

The comparative fecundity of yellow and red shelled snails is a matter of some consequence in connection with a later point. The figures for the three annual series (table 96) prove that the general rate of fecundity is practically the same

for both classes of adults, but the proportion of young snails is higher in the red class. This means only that the latter kind of adult begins to reproduce earlier, and hence bears more numerous advanced young at the seasons when the present material was collected.

TABLE 97.—*Partula otaheitana rubescens*, Papenoo Valley. Statistics of heredity.

	1906.			1908.		
	Yellow young.	Red young.	Total.	Yellow young.	Red young.	Total.
Yellow adults. ....	1	3	4 [26.6 p. ct.]	16	6	22 [18.5 p. ct.]
Red adults. ....	2	9	11 [73.3 p. ct.]	56	41	97 [81.5 p. ct.]
Total. ....	3 [20 p. ct.]	12 [80 p. ct.]	15	72 [60.5 p. ct.]	47 [39.5 p. ct.]	119
	1909.			All years.		
	Yellow young.	Red young.	Total.	Yellow young.	Red young.	Total.
Yellow adults. ....	51	15	66 [37.9 p. ct.]	68	24	92 [29.8 p. ct.]
Red adults. ....	55	53	108 [62.0 p. ct.]	113	103	216 [70.1 p. ct.]
Total. ....	106 [60.9 p. ct.]	68 [39.1 p. ct.]	174	181 [58.7 p. ct.]	127 [41.2 p. ct.]	308

TABLE 98.—*Partula otaheitana rubescens*, Papenoo Valley. Percentage of yellow type in adult and embryonic populations. (Red type equals 100 per cent minus the figures for yellow.)

Series.	Adults.				Embryonic young, per cent.
	Percentage in population.	Percentage in gravid population.	Percentage bearing young taken once.	Percentage bearing young repeated.	
1906, yellow. ....	27.14	37.50	28.57	26.66	20.00
1908, yellow. ....	23.33	20.00	21.75	18.49	60.50
1909, yellow. ....	35.71	40.12	37.73	37.93	60.92
All yellow. ....	30.70	34.76	31.22	29.87	58.76

The statistics of heredity (table 97) are astounding, on account of the great preponderance of yellow individuals in the embryonic series. Only a few snails of the 1906 collection were gravid, and their young conform closely to the adults in regard to the relative numbers of yellow and red individuals. But in the other two series, while the yellow adults naturally produce a larger proportion of similarly colored snails, the red adults bear yellow young in more than 50 per cent of the cases. The result is a great excess of yellow young as compared with the relative number of yellow adults in the whole population, in the gravid class and in that section of the gravid group which bears advanced embryonic young, whether these last-circumscribed adults are taken once only or once for each of their classifiable young (table 98). The figures in the fourth column are slightly lower than those in the first, for reasons given above, which relate to differences in the rate of production of the yellow and red classes. But when all allowances are made, the high figures for yellow young produced by the 1908 and 1909 series indicate a fact of real consequence.

Either some of the yellow young are destined to become red in later life (for which there is some evidence, to be adduced below) or else the process of elimination bears most heavily upon the lighter-colored individuals during post-embryonic life, to an extent which brings the 60 per cent of yellow young down to about 30 per cent by the time maturity is attained by the survivors. Possibly the color-complexion of the whole population is changing from a preponderating red to a preponderating yellow. This supposition is one which can be directly tested only by an examination of the Papenoo Partulæ after the lapse of a few years.

## FAARUMAI, TIAREI, AND MAHAENA VALLEYS.

In the collections from five valleys of the sector immediately to the eastward of Papenoo, *rubescens* is exceedingly rare or absent. It does not appear among 600 adults from Farapa, a valley that lies next to Papenoo, and is also missing in a series of more than 400 mature snails from Vahii, the fifth valley to the east of Papenoo. The significance of the rarity or absence of this form, in places that support large and flourishing colonies of *P. o. affinis*, needs no further discussion.

TABLE 99.—*Partula otaheitana rubescens*, Faarumai, Tiarei, and Mahaena Valleys. General statistical description.

MEAN VALUE.								
Valley.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.	
		mm.	mm.	p. ct.	mm.	mm.	p. ct.	p. ct.
Faarumai....	19	20.5395 ± .1382	11.8578 ± .0907	57.6569 ± .5225	10.7632 ± .0689	8.2053 ± .0628	76.4474 ± .3839	52.2368 ± .3129
Tiarei.....	15	19.9833 ± .1266	11.6467 ± .0746	58.3000 ± .5135	10.2733 ± .0538	7.9000 ± .0492	76.9000 ± .5313	51.3000 ± .2310
Mahaena....	6	18.5833 ± .1298	11.1667 ± .0757	60.0000 ± .5450	9.8667 ± .0668	7.5667 ± .0519	76.1667 ± .5877	53.0000 ± .1377
STANDARD DEVIATION.								
Faarumai....	19	0.8931 ± .0977	0.5861 ± .0641	3.3758 ± .3695	0.4450 ± .0487	0.4059 ± .0444	2.4809 ± .2715	2.0220 ± .2213
Tiarei.....	15	.7272 ± .0895	.4287 ± .0527	2.9484 ± .3631	.3087 ± .0380	.2828 ± .0348	3.0506 ± .3754	1.3266 ± .1633
Mahaena....	6	.4713 ± .0918	.2749 ± .0535	1.9791 ± .3854	.2427 ± .0472	.1885 ± .0367	2.1344 ± .4156	.5000 ± .0974

In the three valleys inhabited, the small collections present very different color complexes. In Faarumai, 7 out of 19 are yellow (plate 27, fig. 12) while the rest usually display a ruddy yellow-brown (plate 27, figs. 13 to 15) not exactly like the "red" of Papenoo shells. In Tiarei, 11 out of 15 are a beautiful yellow (plate 27, figs. 16 and 17) sometimes with a deep purple apex; the others are "red" (plate 27, fig. 18). In Mahaena, finally, all of the 6 shells (plate 27, fig. 19) are clearly allies of the "red" Papenoo examples.

The statistical comparison of the three small series (table 99) is interesting because there is a regular and consistent reduction in all of the absolute measures in passing eastward. The stoutness of the whole shell increases with similar consistency, but in the other proportionate measures there is no such regularity.

In Faarumai no shell bears a pillar tooth. One of the 15 specimens from Tiarei shows a trace of this structure. Of the 6 shells from Mahaena, all possess well-developed prominences.

The statistics of fecundity (table 100) show a high rate of productivity; the season of collection was the drier period of July and August, when also the 1908 and 1909 collection from Papenoo were obtained.

TABLE 100.—*Partula otaheitana rubescens*, Faarumai, Tiarei, and Mahaena Valleys.

FECUNDITY.								
	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Per cent for all.	Per cent for gravid.
Faarumai.....	9	8	88.8	18	20	38	4.2	4.7
Tiarei.....	15	15	100	25	23	48	3.2	3.2
Mahaena.....	6	6	100	9	9	18	3.0	3.0

HEREDITY, FAARUMAI.				HEREDITY, TIAREI.			
	Young, yellow.	Young, red.	Total.		Young, yellow.	Young, red.	Total.
Yellow, adults..	9	0	9	Yellow, adults ..	10	5	15
Red, adults. . .	7	4	11	Red, adults. . . .	4	4	8
Total.....	16	4	20	Total.....	14	9	23

The figures of heredity possess some interest (table 100). In Faarumai the same excess of yellow young discovered in Papenoo recurs. In Tiarei a stable condition of the colony is indicated. The red individuals of Mahaena produced nine young of their own kind.

#### PARAURA VALLEY.

In this locality *rubescens* is represented by 89 adults, which constitute 13.3 per cent of the *otaheitana* population. They are very beautiful in color (plate 27, figs. 20 to 26), and display well-marked subordinate types of coloration in both of the primary classes called yellow and red; the darker tinge of the upper coils spreads down the spire in more than 80 per cent of the light shells (fig. 22), and in about 60 per cent of the red shells (fig. 25). Where decortication occurs, it affects the body whorl especially, so that the contrast of the deeper whorl spire is heightened (fig. 26).

In statistical characters (table 101) the colony as a whole comprises shells that, as compared with those of Mahaena, are slightly longer, far narrower, and greatly lessened in the proportion of the whole shell. The aperture is much larger on the whole, somewhat narrower in proportions, and decidedly stouter in relation to shell length. The tooth is developed to some degree in 65 per cent of the shells.

When the yellow and red classes are compared (table 101) they show marked differences that are especially noteworthy in the proportions of the whole shell and in the relation of aperture length to shell length. The aperture of the lighter shells is distinctly larger in both absolute dimensions.

The fecundity of this colony (table 102) was high at the time of collection, as regards the proportion of gravid individuals, but the average number contained in the brood-chamber was not large.

TABLE 101.—*Partula otaheitana rubescens*, Paraura Valley. Statistical description and analysis.

Character.	Mean value.			Difference, yellow compared with red.	Standard deviation.		
	All (89).	Yellow (67).	Red (22).		All (89).	Yellow (67).	Red (22).
Shell:							
Length, mm. ....	19.1545±.0734	19.1530±.0901	19.1591±.1140	-0.0061±.1453	1.0273±.0519	1.0935±.0637	0.7925±.0806
Width, mm. ....	10.8438±.0369	10.9000±.0445	10.6728±.0557	+ .2272±.0712	.5158±.0261	.5397±.0314	.3875±.0394
Proportions, p. ct. .	56.6798±.1570	57.0373±.1880	55.5910±.2075	+1.4463±.2800	2.1958±.1110	2.2812±.1329	1.4432±.1467
Aperture:							
Length, mm. ....	9.7899±.0383	9.8582±.0470	9.5818±.0488	+ .2764±.0677	.5363±.0271	.5704±.0332	.3393±.0345
Width, mm. ....	7.6708±.0280	7.7089±.0336	7.5546±.0443	+ .1543±.0556	.3915±.0198	.4080±.0237	.3085±.0313
Proportions, p. ct. .	78.4101±.1750	78.2463±.2074	78.9090±.3086	- .6627±.3718	2.4478±.1237	2.5176±.1466	2.1460±.2182
Length aperture ÷ length shell, propor- tions, p. ct. ....	51.0618±.1325	51.4253±.1535	49.9546±.1876	+1.4707±.2424	1.8539±.0937	1.8633±.1085	1.3048±.1326
Tooth. ....	1.9776±.0660	1.9105±.0749	2.0819±.1346	- .1714±.1540	.9238±.0467	.9091±.0530	.9360±.0952

TABLE 102.—*Partula otaheitana rubescens*, Paraura Valley.

FECUNDITY.									HEREDITY.			
	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young	Total contents.	Average for gravid.	Average for all.		Young, yellow.	Young, red.	Total.
Adults:									Adults:			
Yellow.....	67	58	86.5	88	61	149	2.6	2.2	Yellow..	57	4	61
Red.....	22	20	90.9	27	24	51	2.5	2.3	Red.....	13	11	24
All.....	89	78	87.6	115	85	200	2.5	2.2	All.....	70	15	85

The inheritance of the yellow character is rather strict in the offspring of yellow individuals, but as in Papenoo and Faarumai the red adults bear more yellow young than red young (table 102). The facts seem to indicate that the yellow character is dominant in a Mendelian sense in crosses between adults of contrasted color, which would tend to be somewhat frequent where the lighter type exceeds the darker to the degree shown in Paraura. The whole question of a Mendelian analysis, however, is best relegated to a later point; for the present, the essential fact is that as heretofore the two color-classes breed reciprocally.

#### PAPEIHA VALLEY.

Papeiha Valley is a large element of the second order of size, bearing two rivers (plates 9, 10, and 14). Although its radial extent is less than that of many others, such as Temarua and Pirai, its watershed is broad and extensive. Between it and Paraura several small ravines are cut in what is a relatively compact sector of the island. A few snails were collected in one of these ravines, Faatautia, but none of them belonged to *rubescens*, although the locality was quite as favorable, apparently, as the contiguous valleys of larger size.

The adult specimens of *rubescens* from Papeiha number 112 and fall into the two classes of red (plate 27, figs. 30, 31 and 35) and lighter (plate 27, figs. 27 to 29 and 34) shells, but the latter class comprises a distinct subdivision of white decorticated examples—10 out of 71 (plate 27, fig. 27). Decortication is virtually complete,

as in this section, or it is very slight if it occurs at all; apparently, then, it is manifested on account of a defect in the constructive tissues in certain individuals, and is not to be interpreted as an environmental effect *per se*.

A unique parti-colored form occurs in this valley in small numbers, where the basal half of the main whorl lacks the clear red of the rest (plate 27, figs. 32, 33, 36, 37).

The colony as a whole comprises large and vigorous snails (table 103), but one extraordinarily small reddish mutant occurs (plate 27, fig. 31). It is scarcely larger than specimens of the dextral *affinis* which live here, but it is a complete miniature of the true *rubescens* in all respects of color, coil, surface, and form.

When the three color types are compared on the basis of statistical characters (table 103), they exhibit certain differences, some of which are significant. This is especially true of the red shells as contrasted with the clear yellow group, for the former are distinctly narrower absolutely and more slender proportionally, both in the case of the whole shell and in that of the aperture. The "white" and clear "yellow" classes do not differ markedly.

TABLE 103.—*Partula otaheitana rubescens*, Papeiha Valley. Comparison of color-classes.

MEAN VALUE.									
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index. <sup>1</sup>
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
		mm.	mm.	p. ct.	mm.	mm.	p. ct.	p. ct.	
White...	10	19.8000±.1386	11.2400±.0954	56.3000±.3276	10.1000±.0972	7.7400±.0655	76.9000±.4069	51.0000±.3472	1.1000±.2122
Yellow...	61	20.1025±.0753	11.3689±.0357	56.3525±.1939	10.2246±.0388	7.8836±.0257	77.1393±.2298	50.8279±.1396	1.0000± 0
Red...	40	20.2625±.1330	11.1700±.0664	55.3500±.2585	10.1600±.0629	7.7450±.0536	76.3000±.3102	50.1250±.1779	1.0000± 0
All.	111	20.1320±.0633	11.2856±.0327	56.1829±.1501	10.1901±.0325	7.8207±.0262	76.8153±.1744	50.5901±.1072	1.0089±.0060
STANDARD DEVIATION.									
White...	10	0.6500±.0980	0.4476±.0674	1.5362±.2316	0.4560±.0687	0.3072±.0463	1.9078±.2877	1.6278±.2448	0.9950±.1500
Yellow...	61	.8719±.0532	.4143±.0252	2.2458±.1371	.4496±.0274	.2986±.0182	2.6614±.1625	1.6167±.0987	0
Red...	40	1.2474±.0940	.6222±.0469	2.4243±.1828	.5902±.0445	.5029±.0379	2.9086±.2193	1.6686±.1259	0
All....	111	.9889±.0448	.5106±.0231	2.3439±.1061	.5075±.0230	.4100±.0185	2.7245±.1233	1.6741±.0758	.0940±.0042

<sup>1</sup>The numbers are respectively 10, 61, 41=112.

The tooth is completely lacking in all of the shells, with the sole exception of one white example, which exhibits a faint trace of this structure. It may be noted here that the tooth never appears in shells from the valleys throughout the rest of the range of *rubescens*.

In fecundity at the time of collection (table 104) the red-shelled snails were more active reproductively, but the percentage of young for each gravid adult does not exceed the figure for the yellow class or for the two lighter groups taken together.

As regards the heredity of color-characters (table 104), it is clear that the "white" class is made up of snails from the yellow, or at least from another group, for not a single immature snail-shell was "white." It is interesting to note that all of the young from such adults were yellow, and never red. Contrasting the red snails with those of the other two classes taken together, it appears that the former



kind is proportionately less numerous in the series of offspring than it is in the whole population, or in the group of bearing adults. The excess is not so marked here, however, as it is in the colonies described earlier.

TABLE 104.—*Partula otaheitana rubescens*, Papeiha Valley.

FECUNDITY.									HEREDITY.			
	Rec-ords.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for all.	Average for gravid.		Young, yellow.	Young, red.	Total.
Adults:									Adults:			
White.	10	8	80.0	9	14	23	2.3	2.9	White..	14	0	14
Yellow	61	49	80.3	64	55	119	1.9	2.4	Yellow..	48	7	55
Red..	40	35	87.5	41	45	85	2.1	2.4	Red....	18	27	45
All.....	111	92	82.9	114	114	228	2.0	2.5	All.....	80	34	114

## HAAVINI VALLEY.

The next representative collection of *rubescens* was secured in Haavini Valley, on the northern side of the peninsula, Taiarapu, where 214 adults were obtained. In two valleys of the extreme southwest of Tahiti nui, namely, Utuufai and Faone, 5 and 2 adults respectively were found, and in Tehoro, on the northwestern part of Taiarapu, a single example was collected. These representatives of what must be scattered and weak colonies in imminent danger of extinction present no features of special interest.

The colony of Haavini comprises only 7 dark individuals, of a brown-reddish color (plate 27, figs. 43 and 44); the "yellow" shells (207 in number) fall into two clearly marked subdivisions, in one of which the spire is uniform with the body-whorl in color (plate 27, figs. 38 and 39), while in the other a deep tinge grading into purple marks the apex (plate 27, figs. 40 to 42). Most of the red shells have the tip darkened.

TABLE 105.—*Partula otaheitana rubescens*, Haavini Valley.

MEAN VALUE.								
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.	
		mm.	mm.	p. ct.	mm.	mm.	p. ct.	p. ct.
Yellow, A. . . .	54	19.6945±.0877	11.1000±.0431	56.3889±.2410	10.0778±.0453	7.7000±.0333	76.3333±.2183	51.2777±.1790
Yellow, B. . . .	153	19.6585±.0503	10.8628±.0264	55.3432±.1367	9.9327±.0272	7.6216±.0199	76.7614±.1337	50.5523±.0987
Yellow, all....	207	19.6679±.0888	10.9242±.0468	55.6160±.2460	9.9706±.0478	7.6421±.0349	76.6497±.2320	50.7415±.1789
Red.....	7	19.9643±.1649	11.2715±.1170	56.5000±.5940	10.3000±.0545	7.8429±.0757	76.7857±.4859	51.5000±.4088
All.....	214	19.6776±.0426	10.9355±.0228	55.6449±.1188	9.9813±.0230	7.6486±.0169	76.6542±.1118	50.7666±.0863
STANDARD DEVIATION.								
Yellow, A. . . .	54	0.9558±.0620	0.4698±.0305	2.6261±.1704	0.4939±.0320	0.3631±.0235	2.3785±.1543	1.9500±.1266
Yellow, B. . . .	153	.9225±.0355	.4842±.0195	2.5078±.0966	.4986±.0192	.3653±.0141	2.4515±.0945	1.8106±.0698
Yellow, all....	207	.9313±.0628	.4908±.0331	2.5794±.1739	.5015±.0338	.3664±.0248	2.4318±.1640	1.8752±.1265
Red.....	7	.6468±.1166	.4590±.0827	2.3299±.0420	.2138±.0385	.2969±.0534	1.9059±.3436	1.6036±.2891
All.....	214	.9250±.0301	.4939±.0161	2.5764±.0840	.4981±.0163	.3660±.0119	2.4244±.0790	1.8718±.0610

The statistics of the seven shell characters (table 105) show that the colony as a whole is made up of smaller shells than those of Papeiha—a fact that is more important for the general summary at a later point. As stated earlier, no shell exhibits a pillar tooth. In the next place, the few red shells are collectively larger and relatively stouter than the yellow ones, and the aperture is notably *larger* with reference to the whole shell. Hitherto the red shells have been smaller than the others. Finally, it appears that the two subordinate classes of yellow shells differ in certain of their absolute and proportional measurements, with statistical significance. Unless there is some degree of selective mating, it is difficult to account for the observed differences.

The fecundity of the two classes is not equivalent (table 106), but in view of the small number of red adults no great significance can be attributed to the discrepancy. The statistics of heredity (table 106) are also doubtful as far as the red adults are concerned, yet it is interesting to find that these produced no red young in the cases actually examined and that the red offspring came from yellow parents.

TABLE 106.—*Partula otaheitana rubescens*, Haavini Valley.

FECUNDITY.									HEREDITY.			
	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Per cent for all.	Per cent for gravid.		Young, yellow.	Young, red.	Total.
Adults:									Adults:			
Yellow	207	177	85.5	264	177	441	2.1	2.5	Yellow..	174	3	177
Red..	7	5	71.4	8	4	12	1.7	2.4	Red ....	4	0	4
All. . .	214	182	85.4	272	181	453	2.1	2.5	All . . . .	178	3	181

## TAUTIRA VALLEY.

Tautira is the largest valley of the peninsula, Taiaapu or Tahiti iti, and resembles Papenoo in that its innermost portion consists of the principal crater-basin of the whole land-mass. The valley runs outward in a direction a little to the west of north, and is traversed by a large river. The boundaries of the whole valley are high and well marked.

Less than 100 examples of *rubescens* were secured here; while these agree in general with the shells of the Haavini colony in ground-colors (plate 27, figs. 45 to 48), yet the deep tinge, which is so characteristic a feature of the spire in the shells of that valley, is either entirely lacking or greatly reduced in Tautira examples. Another difference consists in the preponderance of red (fig. 48) and reddish-orange shells (figs. 46 and 47), of which there are 59 as compared with 23 of the yellow type.

The statistical characters of the three distinguishable color-classes (table 107) show remarkable differences between the component groups. The clear red shells are the smallest in absolute measures, like their counterparts in the valleys of Tahiti nui, although in Haavini the relation was the opposite. In no shell is a pillar tooth developed even as a trace.

The snails secured in this valley could not be expanded, owing to the exigencies of travel at the time, for the night's camp was made on an islet of the coral reef

where there was no fresh water to use for the extension of the animals. Therefore the statistics of fecundity and heredity (table 108) are few and unsatisfactory, but in the latter case they prove that adults of each type of color produce young of the contrasted kind as well as their own.

TABLE 107.—*Partula otaheitana rubescens*, Tautira Valley.

MEAN VALUE.								
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.	
Yellow.....	23	<i>mm.</i> 20.5326 ± .0657	<i>mm.</i> 11.9696 ± .0590	<i>p. ct.</i> 58.3696 ± .2822	<i>mm.</i> 10.6130 ± .0387	<i>mm.</i> 8.3521 ± .0478	<i>p. ct.</i> 78.5000 ± .3369	<i>p. ct.</i> 51.8043 ± .1964
Red orange...	53	20.1651 ± .0724	11.8887 ± .0453	59.0095 ± .1977	10.4811 ± .0423	8.2320 ± .0372	78.5000 ± .2106	51.9321 ± .1436
Red.....	6	20.0833 ± .1522	11.5333 ± .1248	58.0000 ± .5379	10.3667 ± .1131	8.0667 ± .1119	78.3333 ± .3700	51.5666 ± .4878
Red, all.....	59	20.1568 ± .0668	11.8525 ± .0436	58.9068 ± .1877	10.4695 ± .0398	8.2153 ± .0355	78.4830 ± .1928	51.9068 ± .1381
All.....	82	20.2622 ± .0530	11.8854 ± .0357	58.7561 ± .1577	10.5098 ± .0310	8.2536 ± .0293	78.4878 ± .1903	51.8780 ± .1320
STANDARD DEVIATION.								
Yellow.....	23	0.4670 ± .0464	0.4195 ± .0417	2.0065 ± .1995	0.2755 ± .0274	0.3400 ± .0338	2.3957 ± .2382	1.3968 ± .1389
Red orange...	53	.7815 ± .0512	.4890 ± .0320	2.1334 ± .1397	.4568 ± .0299	.4018 ± .0263	2.2737 ± .1489	1.5498 ± .1015
Red.....	6	.5527 ± .1076	.4533 ± .0882	1.9536 ± .3803	.4109 ± .0800	.4064 ± .0791	1.3438 ± .2616	1.7717 ± .3449
Red, all.....	59	.7618 ± .0472	.4974 ± .0308	2.1401 ± .1327	.4537 ± .0281	.4053 ± .0251	2.1978 ± .1363	1.5743 ± .0976
All.....	82	.7113 ± .0375	.4796 ± .0252	2.1175 ± .1115	.4166 ± .0219	.3930 ± .0207	2.2554 ± .1346	1.5273 ± .0933

TABLE 108.—*Partula otaheitana rubescens*, Tautira Valley.

FECUNDITY (15 RECORDS).		HEREDITY.			
			Young, yellow.	Young, red.	Total.
Gravid.....	14	Adults: Yellow..... Red-orange..... Red.....	4 8	1 2	5 10
Gravid, p. ct.....	93.3				
Eggs.....	23				
Young.....	15	Total.....	12	3	15
Total contents.....	38				
Average for gravid....	2.7				
Average for all.....	2.5				

## AIURUA VALLEY.

With this valley we reach the limit in Taiarapu of the range of *rubescens*. In Aionifaa Valley, which lies between Tautira and Aiurua, a small collection of only 19 *Partulæ* was obtained, one of which was a typical reddish-orange *rubescens*; this snail we may ignore, in order to pass on at once to the colony in the terminal valley.

Of 119 adult individuals, 101 belonged to the class distinguished by a yellow ground-color; 20 possessed the deeply-tinged spire (plate 27, fig. 50), while 81 were clear to the apex (plate 27, fig. 49). The remaining 18 shells exhibited a deep ruddy-brown color (plate 27, fig. 51; plate 28, figs. 1 and 2), and they are by far the darkest

examples of the whole *rubescens* series; indeed, in depth of color some of them rival the brown *affinis* which inhabits this and neighboring valleys. In statistical characters (table 109) the two subordinate divisions of the yellow class are substantially alike; only in the proportions of the aperture is there an essential dissimilarity. The red-brown shells as a class are distinctly different; they are smaller in all four of the absolute measures, and they are narrow in the proportionate figures relating to the shell as a whole and to the aperture, while finally their apertures are longer in proportion to the length of the whole shell. In some but not in all of these relations to the yellow class they resemble the Tautira and Tahiti nui shells, and differ from the red class of Haavini.

TABLE 109.—*Partula otaheitanus rubescens*, Aiurua Valley.

MEAN VALUE.								
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.	
		mm.	mm.	p. ct.	mm.	mm.	p. ct.	p. ct.
Yellow, A. . . .	81	20.3858 ± .0731	11.7642 ± .0356	57.8457 ± .1953	10.3074 ± .0395	7.9913 ± .0280	77.6852 ± .1794	50.6605 ± .1365
Yellow, B. . . .	20	20.4000 ± .1042	11.7400 ± .0492	57.5500 ± .2880	10.4000 ± .0552	7.8800 ± .0466	75.7500 ± .2935	50.8000 ± .1913
Yellow, all. . . .	101	20.3886 ± .0622	11.7594 ± .0302	57.7871 ± .1669	10.3257 ± .0296	7.9693 ± .0245	77.3019 ± .1632	50.6881 ± .0508
Red. . . . .	18	19.8889 ± .1979	11.3667 ± .0734	57.2222 ± .4364	10.1112 ± .0715	7.7778 ± .0499	76.9444 ± .3276	50.8333 ± .3179
All. . . . .	119	20.3130 ± .0616	11.7000 ± .0294	57.7017 ± .1568	10.2933 ± .0278	7.9403 ± .0225	77.2479 ± .1476	50.7101 ± .1096
STANDARD DEVIATION.								
Yellow, A. . . .	81	0.9750 ± .0517	0.4759 ± .0248	2.6065 ± .1379	0.5281 ± .0279	0.3746 ± .0198	2.3939 ± .1267	1.8220 ± .0965
Yellow, B. . . .	20	.6910 ± .0737	.3262 ± .0348	1.9096 ± .2036	.3660 ± .0390	.3088 ± .0329	1.9461 ± .2075	1.2688 ± .1353
Yellow, all. . . .	101	.9257 ± .0440	.4507 ± .0213	2.4869 ± .1180	.4411 ± .0209	.3652 ± .0173	2.4311 ± .1154	1.7275 ± .0359
Red. . . . .	18	1.2450 ± .1399	.4619 ± .0519	2.7448 ± .3086	.4496 ± .0505	.3137 ± .0353	2.0608 ± .2316	2.0000 ± .2248
All. . . . .	119	.9969 ± .0435	.4738 ± .0208	2.5356 ± .1109	.4490 ± .0196	.3644 ± .0159	2.3877 ± .1044	1.7722 ± .0775

Only 9 individuals provided records of fecundity and heredity. All of these were gravid and contained 17 eggs, together with 13 advanced young. They belonged to the yellow class and bore 7 young with and without the red tip, as well as 6 red offspring. The paucity of data, however, renders these relations of little value in this case.

## OOPU VALLEY.

Up to this point, the description of the several colonies of *rubescens* has followed the regular geographical sequence from the most northerly valley of Tuauru down the eastern coast of Tahiti nui and around the north and east sides of Taiarapu to Aiurua, with which valley this form stops. Now it is necessary to return to Tahiti nui, so as to consider the large and flourishing colony in Oopu Valley, which lies just south of the main mountain ridge terminating at the extreme southeastern point of the major island-mass. Obviously the region about Oopu articulates more directly with the eastern sector than with those parts of Taiarapu in which *rubescens* occurs, but as the Oopu colony is the only one on the south side—excepting a single

example from Apirimaue—it has seemed best to consider consecutively the colonies on the north and east before taking up the Oopu shells.

It is a fortunate circumstance that the collection from this valley comprises a full series of individuals that are at the same time the largest and most beautiful specimens obtained in Tahiti. It consists of 272 adults and 95 adolescents, while the number of advanced embryonic young dissected out of the former amount to 267.

Classifying the material on the basis of color, each of the two primary divisions of yellow and red shells may be still further divided (table 110). Whitish-yellow individuals form Group I (plate 28, figs. 3 and 4), and amount to about 7 per cent of all; no adolescent shells were of this color, and no embryonic shell was light enough to be assigned to this group; hence the attenuation of the yellow is something that comes about in later life. Among these shells, about two-thirds have the spire deeply tinged with purple—Section IB (fig. 4) as distinguished from IA. The purer yellow shells form Group II (plate 28, figs. 5 to 7), with light-spined (fig. 5) and dark-spined members (figs. 6 and 7) in the proportion of 3 to 5; the adults of this group constitute 30 per cent of their respective series. When Groups I and II are combined, the percentages for the three growth-periods become more alike. Group III consists of reddish-orange shells (plate 28, figs. 8 to 10) occurring in small numbers in all three series, and with only half of the adults displaying the dark spire (figs. 9 and 10). The more characteristic red shells number over half of all, and in their division—Group IV (plate 28, figs. 13 to 17)—the purple-spined specimens (figs. 12 and 14 to 17) are 6 times as numerous as the others.

TABLE 110.—*Partula otaheitana rubescens*, Oopu Valley. Numerical relations.

Color-class.	No. of adults, plain spire, A.	No. of adults, tinged spire, B.	Total No. of adults.	No. of adolescents.	No. of embryonic young.	Per cent of adult group.	Per cent of adolescent group.	Per cent of embryonic young.
Yellow-white, I. . . . .	5	11	16	0	0	5.9	0	0
Yellow, II. . . . .	31	51	82	32	96	30.1	33.7	35.9
Red-orange, III. . . . .	19	9	28	5	18	10.3	5.3	6.7
Red, IV. . . . .	23	123	146	58	153	53.7	61.0	57.3
Yellow, I, II. . . . .	36	62	98	32	96	36.0	33.7	35.9
Red, III, IV. . . . .	42	132	174	63	171	64.0	66.3	64.0
Total. . . . .	78	194	272	95	267	100	100	99.9

The partly grown shells (plate 28, figs. 19 to 22) are separable into the same color-groups, whose relative numbers do not agree perfectly with those of the adult divisions only because the total number of adolescents was far smaller, and not fully representative of the population at large. The embryonic shells (plate 28, figs. 18A to 18E) display the distinctive colors very early.

The statistical analysis of the colony (table 111) brings out the primary fact that the four color-divisions exhibit considerable diversity. None of them is consistently different from another in the whole group of absolute measurements, or in the group of proportionate measures. Combining the red-tipped shells into one

section (B), and comparing it with the section comprising shells lacking the deep-tinged spire (A), really significant differences appear. Finally, when the yellow-white and the yellow shells are taken together and contrasted with the group of red and orange-red shells, the differences prove to be slight except in the characters of the aperture. There is no general statement that is warranted by these facts.

TABLE 111.—*Partula otaheitana rubescens*, Oopu Valley. Full statistical analysis.

MEAN VALUE.								
Series.	No.	Shell.			Aperture.			Length aperture + length shell, proportions.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.	
		mm.	mm.	p. ct.	mm.	mm.	p. ct.	p. ct.
Yellow-white, I. . . . .	16	23.4375±.1516	12.9625±.0832	55.5000±.3319	11.8500±.0636	8.9750±.0694	76.6250±.4651	50.8125±.2842
Yellow, II. . . . .	82	22.8414±.0822	12.8610±.0360	56.2927±.1697	11.5341±.0413	8.7098±.0292	75.6219±.2046	50.5366±.1376
Red-orange, III. . . . .	28	22.6786±.1018	13.0000±.0507	57.3214±.2481	11.5928±.0662	8.7000±.0436	75.2857±.3497	51.1785±.1929
Red, IV. . . . .	146	22.7945±.0637	12.8863±.0333	56.5822±.1537	11.4740±.0372	8.6014±.0249	74.9041±.1686	50.3219±.0968
Yellow and red, A. . . . .	78	23.1538±.0915	13.0359±.0427	56.3718±.1911	11.7282±.0431	8.8000±.0306	75.1795±.2192	50.6410±.1398
Yellow and red, B. . . . .	194	22.7062±.0511	12.8382±.0254	56.5618±.1244	11.4454±.0253	8.7124±.0207	75.2114±.1421	50.4485±.0855
Yellow, I, II. . . . .	98	22.9388±.0746	12.8776±.0331	56.1633±.1581	11.5857±.0369	8.7531±.0278	75.6224±.1875	50.5816±.1245
Red, III, IV. . . . .	174	22.7759±.0560	12.9046±.0292	56.7012±.1357	11.4931±.0282	8.6172±.0221	74.9655±.1524	50.4598±.0901
All. . . . .	272	22.8306±.0462	12.8949±.0222	56.5074±.1044	11.5265±.0225	8.6662±.0175	75.2022±.1193	50.5037±.0731
STANDARD DEVIATION.								
Yellow-white, I. . . . .	16	0.8992±.1072	0.4935±.0588	1.9684±.2347	0.3775±.0450	0.4115±.0491	2.7585±.3289	1.6852±.2009
Yellow, II. . . . .	82	1.1042±.0581	.4833±.0254	2.2779±.1200	.5542±.0292	.3925±.0206	2.7470±.1447	1.8475±.0973
Red-orange, III. . . . .	28	.7986±.0718	.3982±.0358	1.9466±.1754	.5196±.0468	.3422±.0308	2.7433±.2473	1.5131±.1364
Red, IV. . . . .	146	1.1420±.0450	.5966±.0235	2.7536±.1087	.5550±.0263	.4455±.0176	3.0195±.1192	1.7347±.0684
Yellow and red, A. . . . .	78	1.2000±.0647	.5588±.0302	2.5031±.1351	.5645±.0305	.4009±.0216	2.8711±.1550	1.8308±.0988
Yellow and red, B. . . . .	194	1.0547±.0361	.5247±.0179	2.5699±.0875	.5222±.0178	.4273±.0146	2.9355±.1004	1.7666±.0604
Yellow, I, II. . . . .	98	1.0957±.0527	.4860±.0234	2.3209±.1118	.5421±.0261	.4076±.0196	2.7526±.1326	1.8276±.0880
Red, III, IV. . . . .	174	1.0950±.0396	.5709±.0206	2.6544±.0959	.5512±.0199	.4321±.0156	2.9801±.1078	1.7628±.0637
All. . . . .	272	1.1298±.0327	.5420±.0157	2.5523±.0738	.5497±.0159	.4284±.0124	2.9172±.0844	1.7874±.0517

The percentage of fecund individuals (table 112) averages about 91 per cent, and in consequence the number of embryonic young is satisfactorily large. There are no noticeable indications of a differential fertility, which might give an advantage to one or to another color-class.

TABLE 112.—*Partula otaheitana rubescens*, Oopu Valley. Fecundity.

Series.	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for all.	Average for gravid.
Yellow-white, I. . . . .	16	14	87.5	15	20	35	2.17	2.50
Yellow, II. . . . .	82	76	92.7	102	85	187	2.28	2.46
Red-orange, III. . . . .	28	26	92.8	39	29	68	2.42	2.61
Red, IV. . . . .	146	131	89.7	193	133	326	2.23	2.45
Yellow, I, II. . . . .	98	90	91.8	117	105	222	2.26	2.46
Red, III, IV. . . . .	174	157	90.2	232	162	394	2.26	2.51
All. . . . .	272	247	90.8	349	267	616	2.26	2.49

The statistics of heredity (table 113) disclose certain interesting facts. In the first place, the class of yellow-white adults (I) is not represented in the embryonic series; wherefore it is evident that the distinguishing coloration is a modified one, becoming manifest only during post-embryonic life; without doubt Class I shells are embryonically of Class II, but change later through decortication. Aside from the above qualification, each class produces its own kind and representatives of the other groups as well. Summing up by combining Class II with Class I, and Class III with Class IV, so as to have the two primary divisions of "yellow" and "red" individuals, the numbers of young snails assigned to those two divisions prove to be

TABLE 113.—*Partula otaheitana rubescens*, Oopu Valley.

STATISTICS OF HEREDITY IN FULL.									
	Young, yellow-white, I.		Young, yellow, II.		Young, red-orange, III.		Young, red, IV.		Total.
	A.	B.	A.	B.	A.	B.	A.	B.	
Adults:									
Yellow-white, I, A.....	..	..	2	2	..	..	2	..	6
B.....	..	..	1	8	..	..	5	..	14
Yellow, II, A.....	..	..	11	14	..	..	3	..	28
B.....	..	..	9	19	3	1	25	..	57
Red-orange, III, A.....	..	..	8	2	6	..	4	..	20
B.....	..	..	3	2	1	..	3	..	9
Red, IV, A.....	..	..	4	1	2	..	22	..	29
B.....	..	..	3	7	1	4	89	..	104
	0	0	41	55	13	5	153	0	
Total.....	0		96		18		153		267

HEREDITY OF GROUND-COLOR. SUMMARY.				HEREDITY OF APEX-COLOR. SUMMARY.			
	Young, yellow, I, II.	Young, red, III, IV.	Total.		Young, clear apex, A.	Young, dark apex, B.	Total.
Adults:				Adults:			
Yellow, I, II.....	66	39	105	A, clear apex.....	64	19	83
Red, III, IV.....	30	132	162	B, dark apex.....	143	41	184
Total.....	96	171	267	Total.....	207	60	267

almost equivalent to the numbers in the corresponding groups of adults; the difference of only 9 in a series of 267 is very slight. When we consider the heredity of the deeply-tinged apex, we find a greater discrepancy; the plain-tipped adults produce a large number of similar young, but the dark-spined adults also bear an astonishingly large percentage of young with the plain apex. The total number of Type A shells is so greatly in excess of the contrasted type that we must assume a late appearance of the apical coloration in the majority of individuals destined to have this character as adults. The ease with which the apical darkening can be seen even in young embryonic shells (plate 28, fig. 18 B) serves to remove the objection that errors of observation have been made. Assuming that the facts are correct in

the main, we must come to the conclusion stated above, or else deduce as an alternative that the dark apical coloration is tending to disappear as an hereditary quality of the Oopu colony.

#### APIRIMAUE VALLEY.

In this valley association a single reddish shell was found (plate 28, fig. 23), which is anomalous only in its small size as compared with the *rubescens* of Oopu. In the general color, darkened apex, faint pink lining within the lip, in the absence of the columella tooth, and in its smooth surface, this shell agrees with *rubescens* in general. The majority of the members of this colony are *sinistrorsa* and reversed, but their coloration and shape are such as to exclude the anomalous individual from their kind. Also in this valley there are a few *affinis* with the dextral coil; but they are brown, toothed in most cases, and bear only dextral young. Taking all the data into consideration, we may justly conclude that the single red-shelled sinistral snail is a dwarfed *rubescens*, in some respects like the animal of reduced size that was found in Papeiha Valley.

The class-values of the measurements are as follows:

Shell length.....	16.75 mm.
Shell width.....	10.30 mm.
Shell proportion.....	60.5 per cent.
Aperture length.....	8.70 mm.
Aperture width.....	7.30 mm.
Aperture proportions.....	83.5 per cent.
Length aperture ÷ length shell, proportions.....	51.5 per cent.
Tooth.....	None.
No embryonic contents.	

#### A MENDELIAN INTERPRETATION OF THE HEREDITY OF COLOR.

Throughout the foregoing circumstantial analysis of the several colonies of *rubescens*, the figures relating to the heredity of contrasted yellow and red ground-colors have been given without extended comment, or with only a passing suggestion as to their wider significance. It is now in order to re-examine the data in an endeavor to ascertain whether they indicate a Mendelian mode of inheritance of the two principal colors, with the explicit understanding that whatever its analysis and its results may be, the final formulation in Mendelian terms must depend upon actual experiments, and can not be made solely on such numerical returns as are given in the present descriptive account. When one deals with the phenomena of heredity in wild populations, many difficulties are encountered that are well-nigh insuperable; nevertheless, a method for the analysis of such associations of Partulæ has been devised. Its results suggest, even if they do not conclusively demonstrate, a dominant-recessive relation of the red to the yellow color, and a Mendelian order of their inheritance; hence the conclusions are like those of Lang, who dealt experimentally with identical characters displayed by snails of the genus *Helix*.

The fundamental fact is that wherever the population is mixed the heredity of the ground-color is alternative: an adult or an embryonic shell must be assigned either to the "yellow" class or to the "red" class. Varying shades of the former color are displayed, even to the whiteness of more or less decorticated individuals,



yet all such shells lack the red element on the body-whorls. A reddish apical coloring may be displayed, but this is an independent character, and its presence or absence enters only incidentally into the following discussion. In Oopu and some other places certain shells exhibit an "orange" color, due to a light shading of red over the yellowish ground-color, wherefore such specimens are to be included in the "red" class. Thus, the two main divisions differ according to the "absence of red" and the "presence of red" as a light or deep general tinge. The colors of the embryonic shells are much less intense and therefore less contrasted than those of mature shells, but the same basis for classification may be employed. In itself, the basic fact of alternative inheritance is suggestive of a Mendelian order.

TABLE 114.—*Partula otaheitanus rubescens*. Data for the yellow and red classes.

Valley.	Adult population.					Gravid adults containing young.					Embryonic population.				
	No. of yellow.	No. of red.	Total.	Per cent yellow.	Per cent red.	No. of yellow.	No. of red.	Total.	Per cent yellow.	Per cent red.	No. of yellow.	No. of red.	Total.	Per cent yellow.	Per cent red.
Ahonu.....	79	67	146	54.11	45.88	31	25	56	55.36	44.64	37	30	67	55.22	44.77
Papenoo.....	105	237	342	30.70	69.29	59	130	189	31.22	68.78	181	127	308	58.76	41.23
Paraura.....	67	22	89	75.28	24.72	44	17	61	72.13	27.87	70	15	85	82.35	17.65
Papeiha.....	71	41	112	63.39	36.60	47	28	75	62.66	37.33	80	33	113	70.79	29.20
Haavini.....	207	7	214	96.73	3.27	126	3	129	97.67	2.33	178	3	181	98.34	1.66
Oopu.....	98	174	272	36.03	63.97	74	121	195	37.95	62.05	96	171	267	35.95	64.04
Total.....	627	548	1,175	53.36	46.64	381	324	705	54.04	45.95	642	379	1,021	62.88	37.12
Average.....	104.5	91.3	195.8	59.37	40.62	63.5	54.0	117.5	59.50	40.50	107.0	63.2	170.2	66.90	33.09
Tuauru.....	2	6	8	25.00	75.00	1	3	4	25.00	75.00	4	3	7	57.14	42.86
Faaripoo.....	7	12	19	36.84	63.16	3	5	8	37.50	62.50	16	4	20	80.00	20.00
Tiarei.....	11	4	15	73.33	26.67	11	4	15	73.33	26.67	14	9	23	60.87	39.13
Mahaena.....	0	6	6	0	100	0	5	5	0	100	0	9	9	0	100
Utuufai.....	5	0	5	100	0	3	0	3	100	0	4	0	4	100	0
Tautira.....	23	59	82	28.05	71.95	5	5	10	50	50	12	3	15	80.00	20.00
Aiurua.....	101	18	119	84.87	15.12	8	0	8	100	0	7	6	13	53.84	46.15
Total, 13 valleys..	776	653	1,429	54.30	45.69	412	346	758	54.35	45.65	699	413	1,112	62.86	37.14
Aver., 13 valleys..	59.7	50.2	109.9	54.18	45.81	31.7	26.6	58.3	57.14	42.86	53.8	31.8	85.5	64.09	35.90

The first step is to eliminate the colonies whose representations are too few numerically; these are the associations of Faarumai, Faone, Tehoro, Aionifaa, and Apirimaue. The remaining *rubescens* colonies are 13 in number, whose constitution is given in full in table 114, as regards the relative numbers of "yellow" and "red" individuals (*a*) in the whole adult population, (*b*) in the group of gravid adults containing distinguishable young, and (*c*) in the offspring generation itself. In the six valley series listed in the first part of the table the figures are satisfactorily large even in the case of the embryonic population, which varies from 67 in Ahoruu to 267 in Oopu and 308 in Papenoo. In the other seven series, the offspring generation runs from 4 to 23 only, while in addition the numbers in the adult series are by no means favorable; hence these seven are not to be worked out in detail. Again, the collection yielded only yellow types in Utuufai Valley and only red-shelled snails in Mahaena, so that the question of alternative inheritance does not arise in these two cases. Finally, it must be noted that although the numbers are large in the series from Haavini, placed in the first list, the proportion of red shells is too small to serve for a rigid analysis, such as is made of the remaining five.

Next comes the question as to the stability of the colonies as indicated by the returns. From the figures as given in table 114, it is apparent that the gravid adults constitute entirely satisfactory reproductive samples, so to speak, of their respective associations. Specifically, the proportionate numbers of yellow and red individuals are essentially the same among the parents with classifiable young as among the adults generally. The discordant instances of Tautira and Aiarua occur because circumstances prevented a study of a sufficient number of adults collected; but when we compare the offspring generation with the adults, it appears that wherever both color-types occur in a colony *the percentage of red snails among the offspring is less than the relative numbers of this kind in the adult population and in the group of gravid adults*, with two exceptions of slight degree in the upper list (Ahonu and Oopu) and two in the lower list (Tiarei and Aiurua). In the case of *Helix*, Lang found that the dominant red color was not always displayed by very young snails, but appeared only later; if the genetic facts are the same for *P. o. rubescens*, the smaller percentage of the red type in embryonic populations would be explained.

In the next place, we encounter a difficulty which prevents the combination of the reliable figures for the colonies of the six first-listed valleys into a single series, the fact, namely, that the proportionate numbers of yellow and red individuals are not the same in any two valleys, although, as qualified above, they are essentially stable within the valley. One of these two classes comprises recessive individuals (RR) only, while the other is made up of duplex dominants and heterozygous snails (DD+DR). The proportions of these three genetic classes can not be the same in Haavini, where the red-shelled snails number only 3 per cent, as in Oopu, where such individuals amount to 64 per cent, and hence the figures can not justly be combined.

Each valley association, therefore, must be taken by itself for internal analysis. The problem is to ascertain whether the facts warrant the assumption that one color-type or the other is dominant with reference to its alternate as a recessive, and whether the characters of the young borne by the gravid parents make it possible to assign the adults to the three classes, DD, DR, and RR.

#### OOPU VALLEY.

The colony of Oopu Valley will be taken up first, on account of its apparent stability, and also because larger numbers are at hand for the development of the method by which a Mendelian analysis may be made. At this point, however, it must be frankly stated that the result in this case, *taken by itself*, would indicate the *recessive* character of the red color-factor, which is contrary not only to Lang's results but also to the final conclusion of the present study.

*A. Red color assumed to be dominant.*—The gravid adults and their young provide the data for the treatment of the Mendelian problem. The former are to be classified according to the color characters of their embryonic young, and each parent is to be counted once only, with the following numerical relations:

- (1) Red adults: red young only, 98; red and yellow young, 7; yellow young only, 16=121
- (2) Yellow adults: red young only, 19; red and yellow young, 16; yellow young only, 39=74

By assumption, the 74 gravid yellow adults are RR in composition, while the 121 red adults are DD+DR in a proportion as yet undiscovered.

The yellow parents with young will have mated with DD, DR, and RR adults according to the chance possibilities, and in the case of the RR×RR mating the number can be ascertained; it is 36 per cent of all cases, which follows from the fundamental data given in table 114. Specifically, the number is 36 per cent of 74, or 26.64, taken as 27. These would bear yellow young only (RR×RR=RR+RR). Empirically, however, we find 39 gravid adults of this class; the excess of 39 over the theoretical number of 27, or 12, comprises these RR adults which have mated with DR and not RR, but their young are too few to represent both kinds of expected offspring, as they would according to theory (RR×DR=DR+RR); such adults, if mated with DD, would have borne red young only, and no yellow young. Hence we must correct (2) by transferring to the middle class the 12 RR×DR, with the following result:

(3) Yellow adults: red young only, 19; both kinds, 28; yellow young only, 27=74

But we found that certain adults, bearing yellow young only, amounting to 12 out of 39, really belonged to the middle class; undoubtedly some of the yellow adults bearing red young only would produce yellow offspring as well, if the embryonic contents were more ample. Such individuals are RR in composition by assumption, and their mates would have been DR; they, too, should be placed in the middle class. The only basis for estimating their numbers is the fractions transferred from the third to the middle class, or  $\frac{12}{39}$ . Effecting the transfer of the 6 individuals thus indicated, (3) becomes:

(4) Yellow adults: red young only, 13; red and yellow young, 34; yellow young only, 27=74

The numbers in these three classes stand for the matings of RR parents with DD, DR, and RR snails, respectively, and hence the relative numbers of DD and DR snails in the class of 121 red parents are discovered and defined.

The second part of the present Mendelian analysis consists of a study of the red class of parents classified as in (1), to see how closely their empirical numbers correspond to expectation when the proportions are actually what the treatment of the yellow snails has disclosed, namely, 13:34:27 respectively. As we are now proceeding on the assumption that the yellow color is the recessive member of the pair, the 121 red snails are DD and DR in genetic composition in the proportion of 13:34, or 33.47 and 87.52 individuals, taken as 33 DD and 88 DR.

The 33 red snails of the DD group have had mates of unknown genetic composition, but which would be DD, DR, and RR according to chance proportions. Still, the characters of the unknown mates are not important here, for in all cases the offspring would be red in color, for an RR combination among them would be impossible. Hence at least 33 of the red parents with red young only in (1) are accounted for.

The 88 DR red parents would also have mated with DD, DR, and RR snails according to the chance possibilities derived from the analysis of the yellow class, as formulated in (4). The cross of DR×DD would occur in  $\frac{13}{74}$  of the 88 cases, or

15.5, and the resulting young would all be red in color. The second combination of  $DR \times DR$  would occur in  $\frac{34}{74}$  of 88 instances, or 40.5, and the offspring would be red and yellow; it is true that the proportions among the young would be 3 red to 1 yellow, and therefore if only 1 or 2 were present in the parental brood-pouch, the chances are in favor of the former color being displayed, and hence the real genetic constitution of the known parent would not be indicated. Finally, the third combination of  $DR \times RR$  would come about in  $\frac{27}{74}$  of 88 cases, or 32, and again the offspring would be red and yellow, here in equal numbers. Summing up, on theory there should be:

(5) Red adults: red young only, 48.5; red and yellow young, 72.5 = 121

although we know that one qualification certainly must be made and another is probable; the first is that some of the red adults with red young only would undoubtedly produce yellow young as well, for they are  $DR$  mated with  $DR$ , and not  $DD$ , while the second is that if the relations are the same as in *Helix*, some of the apparently yellow young produced by the parents of the second class of (5) might be red in later life. To some extent, the corrections to be made, if all of the facts about the constitution of the red parents were known, would counterbalance one another.

Before a comparison of the empirical observations of (1) with the theoretical figures of (5) can be made, the former need first to be combined, and then to be corrected in one particular. The 16 red adults that bear yellow young only are, by assumption,  $DR$  mated with  $DR$ , whose young are too few on the average to show both color-types in the offspring generation; hence they are to be assigned to the second class of red parents. In the next place, some of the red parents with red young would undoubtedly produce yellow young also, if their products were sufficiently numerous; hence they too must be transferred to the second class. The only discoverable basis for estimating them is the fractions similarly transferred in the treatment of the yellow class, namely,  $\frac{12}{39}$  of 98, or 32; this fractional number is only approximate, but it is the only one that can be determined on the basis of analytical results. Making the indicated adjustments the empirical figures are:

(6) Red adults: red young only, 66; red and yellow young, 55 = 121

The departure from theory amounts to 17.5 out of 121 cases, or 14.4 per cent.

*B. Yellow color assumed to be dominant.*—We may now make the same kind of analysis, assuming the contrary value for the yellow color-factor, namely, that it is dominant to red. Rearranging the gravid adults of the two series (1) and (2), the classification is as follows:

(7) Yellow adults: yellow young only, 40; yellow and red young, 16; red young only, 19 = 74

(8) Red adults: yellow young only, 16; yellow and red young, 7; red young only, 98 = 121

As the red adults are  $RR$  by assumption, the yellow adults will be  $DD + DR$  in an unknown proportion.

The 121 red adults will have mated with  $DD$ ,  $DR$ , and  $RR$  adults, according to the chance possibilities. Union with  $RR$  would occur in 64 per cent of all cases, which follows from the fundamental data of table 114; that is, 77 are of this kind, and they would bear red young only ( $RR \times RR$ ). Empirically, however, we find 98

which bear red young only. Therefore the excess over 77 or 21 comprises individuals which are RR in composition themselves and which have mated with DR yellow adults, but whose young are too few to include both yellow and red individuals in the expected numbers. Clearly such red adults could not have mated with DD yellow adults, for in that case their young would be all yellow ( $RR \times DD = DR$  only). Hence we must correct (2) above by transferring to the middle class the 21 red adults mated with DR, but which do not provide yellow young, with this result:

(9) Red adults: yellow young only, 16; yellow and red young, 28; red young only, 77 = 121

But we have found that adults bearing red young only, amounting to three-fourteenths of all in that class, really belong to the middle class. Presumably, therefore, some of the adults bearing yellow young only would contain red young also if their offspring were sufficiently numerous to represent their genetic constitution and that of the other parent. Such individuals would have to be RR themselves, and they would have had to mate with DR in order to bear yellow and red young. The only basis for estimating their relative numbers is the three-fourteenths fraction of the red class that had mated with DR, and bore young of one color only. Proceeding on this basis, we may subtract three-fourteenths, or 4, from the first class and add that number also to the middle class, when (9) becomes:

(10) Red adults: yellow young only, 12; yellow and red young, 32; red young only, 77 = 121

Now these three classes stand for the other mates of the red parents whose young have provided the data for the analysis. Hence we have arrived at a determination of the relative numbers of DD and DR in the yellow part of the whole population, unattainable on inspection, which is, specifically, DD : DR : : 3 : 8.

In order to test the truth of the above analysis and its results, we may return to the yellow adults of (7) to see if their embryonic contents correspond to expectation should the proportionate numbers of DD, DR, and RR be as derived from the entirely independent data relating to red parents. Such yellow parents (74) are either DD or DR, in the proportion of 3 to 8, or DD 20 : DR 54.

The 20 DD yellow parents will have mated with DD, DR, and RR in the proportions indicated in (10); but all of their young in all cases would be yellow, for the RR combination is impossible in their offspring.

The 54 DR yellow parents will also have mated with DD, DR, and RR in the proportions of 12:32:7, respectively. Specifically,

$DR \times DD = 5.5$  cases yellow young only.  
 $DR \times DR = 14$  cases yellow and red young.  
 $DR \times RR = 34.5$  cases yellow and red young.

Combining the figures, we have:

(11) Yellow adults: yellow young only, 25.5; yellow and red young, 48.5 = 74

Before we may compare the expected with the actual figures of (7), certain combinations and corrections of the latter must be made. A yellow adult, being DD or DR by assumption, could not bear red young only, whatever its mate; the 19 individuals so classified must therefore be  $DR \times DR$ , whose offspring are not abun-

dant enough on the average to represent the parental possibilities. Hence the second and third classes of (7) are to be combined. Again, it is practically certain that among the yellow adults bearing only yellow young are some that are capable of bearing yellow and red young, of which the latter do not appear, owing to a single offspring only being present. Correcting by the same fractional value of three-fourteenths, which is the sole basis for adjustment that it is possible to discover, we subtract three-fourteenths of 40, or 8.5, from that figure, and add it to the other class, whereupon (7) becomes:

(12) Yellow adults: yellow young only, 31.5; yellow and red young, 42.5 = 74

The contrasted empirical figures differ from the expected numbers by 8.1 per cent.

*Résumé.*—When the red color is assumed to be dominant with reference to yellow, the analysis of the series displaying the recessive color gives the numerical relations of 13:34:27 for the DD, DR, and RR adults, respectively; the test of these figures in the independent DD + DR red class shows a departure of observation from expectation amounting to 14.4 per cent. If yellow is assumed to be dominant, the three genetic classes have the numerical relations of 12 DD:32 DR:77 RR; and the difference between expectation and observation proves to be 8.1 per cent. The assumption as to the dominance of red is favored by the numerical relations of the genetic classes, while the lower percentage of error in the second case tends to support the view that the yellow color is dominant. The method of analysis consists of the treatment in the first instance of the group of gravid adults displaying the color assumed to be recessive, and of an entirely independent study of the DD + DR class, to see how closely the observed facts correspond to deduction. Obviously, the chief difficulty in procedure is to determine how much adjustment is made necessary on account of the small average number of young in the brood-chamber.

#### PAPEIHA VALLEY.

It is here that the bicolored shells are found; they are classified as red because of the presence of that color, even if it does not cover the entire shell. However, a source of error in the assignment of embryonic shells to their correct class arises from the difficulty of detecting the bicolored pattern in the very young individuals; this error would tend greatly to increase the yellow class of offspring at the expense of the other. Here the numerical relations of the two color-classes are reversed in the adult populations, as compared with the Oopu colony, the yellow adults forming 63.39 per cent and the red adults only 36.6 per cent. The yellow parents with young, counted once, are 47 out of 75, or 62.66 per cent; the similar red parents are 28 in number, or 37.3 per cent. Their contents are as follows:

- (1) Red adults: red young, 13; red and yellow young, 7; yellow young, 8 = 28
- (2) Yellow adults: red young, 3; red and yellow young, 3; yellow young, 41 = 47

Assuming that the red color is dominant, we begin with the contrasted individuals that would be RR; in 63 per cent of these the mate would be a similar RR snail, or 29.6 cases to be taken as 30. The difference between their theoretical

figure and 41 exists because some of the yellow adults with yellow young only have mated with DR snails, but their young are so few as to lack the expected red types. The transfer of  $\frac{11}{41}$  of the third group in (2) is indicated, and the same degree of correction may be made for the first group, viz, yellow adults with red young only. The formula thus becomes:

(3) Yellow adults: red young, 2; red and yellow young, 15; yellow young only, 30=47

It may be repeated that these figures stand for the three classes of the mates of the RR yellow snails.

Continuing the test, we may next determine the number of DD and DR individuals in the red class. From (3) we have learned that they are as 2:15, and hence, in the 28 actual specimens, there are 3 DD and 25 DR. The former will have red young only, no matter what their mates might be. The latter will have red young only in  $\frac{2}{47}$  of the 25 DR cases, or in one instance, while in the remaining 24 both kinds of young are expected. Theoretically, then, the expected numbers in the two groups of gravid red adults would be:

(4) Red adults: red young only, 4; red and yellow young, 24=28

Actually, when the figures of the second and third groups of (1) are combined for stated reasons, and when the transfer of  $\frac{11}{41}$  of the 13 individuals of the first group is also made, again for indicated reasons, the figures are as follows:

(5) Red adults: red young only, 9.5; red and yellow young, 18.5=28

The difference between theory and observation amounts to 5.5 cases among 28, or 19.6 per cent.

We may now proceed to deal with the returns on the assumption that yellow color is dominant, using the terms of (1) and (2) without rearranged formulation. Beginning with the red class assumed to be recessive, we find that RR×RR is expected in 37 per cent of 28 cases, or 10; the excess of 13 over 10 is due to the cases where yellow as well as red young should be expected if the average numbers of young were greater. Having corrected the number for the third class by transferring 3, or about one-fourth, to the middle group, we also correct the figures for red adults bearing yellow young to the same fractional amount of  $\frac{3}{13}$ , or 2, and (1) becomes:

(6) Red adults: yellow young, 6; yellow and red young, 12; red young, 10=28

Hence we discover the proportionate numbers of DD and DR yellow adults, which are as 6:12 or as 1:2. Testing by working out the expected results in the case of gravid yellow adults, to be compared with the empirical observations, one-third, or 16, would be DD mated with DD, DR, and RR, and would consequently have all yellow young. Two-thirds, or 31, would be DR, with three kinds of mates as follows:

DR×DD  $\frac{3}{13}$  of 31 = 7 cases, yellow young only.  
 DR×DR  $\frac{6}{13}$  of 31 = 13 cases, yellow and red young.  
 DR×RR  $\frac{5}{13}$  of 31 = 11 cases, yellow and red young.



Combining the expected results for the known DD and DR parents, there should be:

- (7) Yellow adults: yellow young only, 23; yellow and red young, 24=47

Empirically, we find the numbers are 41:6, but we may correct by withdrawing  $\frac{3}{13}$  of the first class or 9.5 for transfer to the second class, when we get:

- (8) Yellow adults: yellow young only, 31.5; yellow and red young, 15.5=47

The divergence between expectation and observation amounts to 18 per cent. The advantage in favor of the assumption that yellow is dominant is so slight as to render the results indeterminate so far as the Papeiha analysis is concerned.

#### PARAURA VALLEY.

In the general population, the yellow individuals constitute 75 per cent, and the red 25 per cent of all; among the gravid adults, however, the former amount to 82 per cent, and the latter to 18 per cent. Classified according to their embryonic contents, the parents are as follows:

- (1) Red adults: red young, 5; red and yellow young, 4; yellow young 8=17  
 (2) Yellow adults: red young, 2; red and yellow young, 2; yellow young 40=44

When the red color is taken as the dominant element, the  $RR \times RR$  combination would occur in 75 per cent of the 44 indicated cases, or 33. The transfer of 7 cases to the middle group of (2) is to be made, but the fractional value of  $\frac{7}{41}$  is too small in the case of the yellow adults with red young to be taken into account. Thus (2) becomes:

- (3) Yellow adults: red young, 2; red and yellow young, 9; yellow young, 33=44

Proceeding further by testing the figures for the DD, DR, and RR classes thus indicated in an analysis of the small group of 17 red adults, we find that 3 are DD and 14 are DR. The former would bear red young only, and  $\frac{1}{22}$  of the latter (or 1) would be of the same nature; the remaining 13 DR red parents would have mated with DR and RR in the theoretical proportion, and their offspring would be red and yellow. Theory would give the following:

- (4) Red adults: red young only, 4; red and yellow young, 13=17

When the figure for the first class of (1) is corrected by the transfer of  $\frac{7}{40}$  of the cases, or 1, and when the other classes are combined, the empirical figures are 4:13, which are identical!

Proceeding on the alternative hypothesis that red is recessive, we find that among such parents, one-fourth of all would be  $RR \times RR$ ; only 1 of the 5 records in the third group is misplaced, therefore. Correcting the number in the first group by subtracting one-fifth of 8, which is 1.6, taken as 2, the numbers become 6:7:4=17. Working out the data of (1) on this basis, we find that 20 yellow adults would be DD mated with DD, DR, and RR, producing yellow young only. Of the 24 DR, 8.5 would bear yellow young only, and 15.5 would produce both kinds. In short, in expectation there should be 28.5 bearing yellow only, and 15.5 of the others; empirically we find the numbers are 40.4, which, when corrected by the transfer of one-fifth or 8 from the first to the second group, become 32:12.



The difference between the expected and the observed figures amounts to 3.5 in 44, or 7.9 per cent. Hence the first assumption as to the dominance of red is supported, in spite of the small numbers available for the analysis.

#### PAPENOO VALLEY.

The classified parents fall into the following groups:

Red adults: red young, 54; red and yellow young, 23; yellow young, 53 = 130

Yellow adults: red young, 10; red and yellow young, 10; yellow young, 39 = 59

When the red color is assumed to be dominant, the  $RR \times RR$  combination would come about in 31 per cent of the 59 cases, or 18. Effecting the transfer of  $\frac{21}{39}$  from the first and third groups to the middle group, the numbers for the three genetic classes become 5 DD:36 DR:18 RR = 59. As the proportions of DD:DR in the class of red parents are 5:36, the absolute numbers prove to be 16 DD:114 DR. The former will all bear red young, whatever their mates, while 10 of the latter, having DD mates, will belong to the same category. According to theory, therefore, there should be 26 parents with red young only, and 104 with both kinds of offspring. The corrected empirical results give 25 and 105, which differ from the expected figures by only 1 out of 130 cases, or 0.7 per cent.

On the contrary assumption, the chances for recessive red parents having mated with similar RR adults are 69 per cent of the 130 cases, or 89.7—a figure which greatly exceeds the actual number of 54 that bear red young only, among which are some that must be capable of bearing both yellow and red offspring as the result of a mating with DR yellow individuals; thus the analysis breaks down.

The facts in the case of the Papenoo colony, when this is taken by itself, afford strong support for the contention that the red and yellow colors constitute a Mendelian pair, of which the former is dominant.

#### AHONU VALLEY.

As the collection from this valley is small, there are relatively small numbers available for consideration. Here the yellow-shelled snails amount to 54 per cent of the population. The parents with distinguishable young are as follows:

Red adults: red young, 19; red and yellow young, 1; yellow young, 5 = 25

Yellow adults: red young, 4; red and yellow young, 1; yellow young, 26 = 31

We need not enumerate the steps in the analysis. When red is assumed to be dominant, the proportion of DD, DR, and RR come out as 3:11:17, respectively. The test in the case of the red adults reveals a difference between expectation and observation amounting to 5.5 out of 25 individuals, or 22 per cent. When the opposite assumption is made, namely, that yellow is dominant, the proportions of DD, DR, and RR prove to be 3:11:11, and the independent test of these relations in the case of the yellow adults results in a discrepancy of 19.3 per cent. The second assumption is favored by the lower indicated error, but only to a very slight degree.

## SUMMARY.

Bringing together the essential facts for the five colonies analyzed in detail (table 114 $\frac{1}{2}$ ), the two series of Papenoo and Paraura support the conclusion that the red color is a Mendelian dominant in its relations to yellow; the series of Papeiha and Ahonu are not conclusive either way, while the results only in the case of the Oopu series distinctly favor the opposite contention.

TABLE 114 $\frac{1}{2}$ .—*Partula otaheitana rubescens*. Summary of the essential results of analyzing the heredity of the red and yellow colors in Mendelian terms.

Valley.	Red color assumed to be dominant.		Yellow color assumed to be dominant.	
	Proportions of DD: DR: RR	Percentage of error in independent test.	Proportions of DD: DR: RR	Percentage of error in independent test.
Oopu . . . . .	13: 34: 27	14.4	12: 32: 77	8.1
Papeiha . . . . .	2: 15: 30	19.6	6: 12: 10	18
Paraura . . . . .	2: 9: 33	0	6: 7: 4	7.9
Papenoo . . . . .	5: 36: 18	0.7	impossibility	
Ahonu . . . . .	3: 11: 17	22	3: 11: 11	19.3

As a rule, the colonies are relatively stable in their color-composition, which would scarcely be the case if the yellow and red were not hereditarily determined. Of course small changes would be expected from year to year, unless the relative numbers of DD, DR, and RR individuals had reached such proportionate relations as to be repeated identically in generation after generation; but the natural fluctuations would be small in an equilibrated population of long standing.

The inheritance of the ground-color is alternative, so far as the observations may be trusted. Among the embryonic snails, the colors are attenuated, and errors in determination have been made without doubt, especially in the case of the Papeiha embryos. But every single original observation has been made by one individual observer in obtaining the basic facts, with no bias other than the endeavor to assign a shell to the yellow or to the red class. Not until the tables were completed did it appear that the two classes of embryonic snails were proportionately represented as in the adult populations or otherwise.

In devising the method for discovering a Mendelian behavior of the color-factors, almost insuperable obstacles were encountered, notably the small numbers of young produced by a single parent, the impossibility of ascertaining the gametic composition of the unknown mate of a gravid adult, and lack of knowledge as to the relative numbers of DD, DR, and RR snails, although in the last connection it was evident that one class would be RR and the other would be DD+DR. According to the procedure adopted, it was first assumed that the yellow class represented RR, and the relative numbers of the three kinds of adults were then ascertained and were tested by the correspondence between the observed and expected relative numbers in the other color-class, *by an entirely independent analysis*. Subsequently the converse assumption was made, and the results were compared with the first conclusions as to their consistency.

In the judgment of the present writer the balance of evidence is in favor of (1) a Mendelian order of inheritance and (2) the dominance of red over yellow when the individual cases are weighted according to their reliability, and when the conclusions of Lang in the analogous case in *Helix* are taken into account. Clearly, however, actual breeding experiments are necessary before the final word can be said.

#### SUMMARY.

Having completed the survey of the whole primary variety, *P. o. rubescens*, we may now bring together the general results which have been obtained through the detailed analysis of its several valley associations. This summary is more interesting than in the case of *P. o. amabilis*, for many reasons: principally because this subspecies is exclusively sinistral, it is simpler in its make-up because it ranges over a far wider territory, and above all because in most of the valleys of its range it exists side by side with another subspecies, *P. o. affinis*, with which it has no reproductive relations.

I. *The relative numbers of rubescens in the otaheitana population and in the total Partula population vary from valley to valley.* The figures referring to the actual collections may be taken only as approximations to the true values without rendering this statement incorrect. In a few localities included in the whole area of habitation, viz, Faaripoo, Mahaena, Utuufai, Faone, Tehoro, and Aiurua, the numbers are so scanty as to indicate a real danger of extermination. The prevalence of *affinis* in those valleys proves that the conditions in themselves are not adverse to Partulæ; hence there are positive and not merely negative reasons for concluding that variations in congenital vigor are displayed by the colonies of *rubescens*.

II. *The general composition of the several rubescens associations varies likewise.* The relative numbers of "yellow" and "red" shells exhibit many different values, even where large numbers of snails were secured. In Haavini the former kind greatly preponderates, while in the next large valley of Tehoro the relation is entirely reversed. Ahonu and Papenoo are also near together, yet their *rubescens* populations show essentially different combinations of the two principal color-classes.

III. *The structural characters of the shells, defined in quantitative terms, differ in the several colonies without revealing any consistent relations to environmental conditions.* The eastern sector, in which most of the colonies are found, is uniformly moist, like the eastern part of Taiarapu and the southeast corner, where Oopu Valley is located. It is theoretically possible that undiscovered influences might vary from valley to valley, with increasing or decreasing power toward the extremes of the range, in such a way as to manifest their effects in the dimensions and proportions of the shells. Nevertheless, there are no empirical indications of such influences or of their effects.

Specifically, the figures given in summary in table 115, the statistical differences with their errors as given in table 116, and the graphic representations of table 117, which show the progressive changes in average values in geographical

order, collectively demonstrate how the several colonies display independent combinations of structural qualities. To cite certain significant comparisons, in the first step (Tuauru to Ahonu), the shells become longer and wider, and possibly stouter, while at the next (Ahonu to Papenoo) they decrease in length but increase in stoutness; from Faarumai to Tiarei there is again a decrease in length with an increase in proportions, but from Tiarei to Mahaena the absolute measures diminish with a certain increase in stoutness; again the shells of Tautira as compared with

TABLE 115.—*Partula otaheitana rubescens*. Statistical summary.

MEAN VALUE.									
Valley.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
		mm.	mm.	p. ct.	mm.	mm.	p. ct.	p. ct.	
Tuauru...	8	19.5000 ± .1333	10.5500 ± .0884	54.0000 ± .4130	9.7000 ± .0754	7.2250 ± .0473	75.1250 ± .4608	49.3750 ± .4034	1.1250 ± .0789
Ahonu...	145	20.6603 ± .0533	11.3166 ± .0296	54.6379 ± .1295	10.2766 ± .0286	7.7662 ± .0236	75.4379 ± .1540	49.6586 ± .1016	2.2809 ± .0675
Papenoo...	336	20.3765 ± .0340	11.3024 ± .0207	55.3690 ± .0865	10.3280 ± .0195	7.6994 ± .0168	74.5268 ± .1104	50.6637 ± .0714	2.4828 ± .0371
Faarumai.	19	20.5395 ± .1382	11.8578 ± .0907	57.6579 ± .5225	10.7632 ± .0689	8.2053 ± .0628	76.4474 ± .3839	52.2368 ± .3129	1.0000 ± 0
Tiarei...	15	19.9833 ± .1266	11.6467 ± .0746	58.3000 ± .5135	10.2733 ± .0538	7.9000 ± .0492	76.9000 ± .5313	51.3000 ± .2310	1.0667 ± .0434
Mahaena.	6	18.5833 ± .1298	11.1667 ± .0757	60.0000 ± .5450	9.8667 ± .0668	7.5667 ± .0519	76.1667 ± .5877	53.0000 ± .1377	3.6667 ± .2052
Paraura...	89	19.1545 ± .0734	10.8438 ± .0369	56.6798 ± .1570	9.7899 ± .0383	7.6708 ± .0280	78.4101 ± .1750	51.0618 ± .1325	1.9776 ± .0660
Papeiha...	111	20.1320 ± .0633	11.2856 ± .0327	56.1829 ± .1501	10.1901 ± .0325	7.8207 ± .0262	76.8153 ± .1744	50.5901 ± .1072	1.0089 ± .0060
Utuufai...	5	19.9500 ± .1206	11.2200 ± .1182	55.7000 ± .8433	10.2600 ± .0886	7.5000 ± .0934	73.7000 ± 1.2568	51.1000 ± .2413	1
Haavini...	214	19.6776 ± .0426	10.9355 ± .0228	55.6449 ± .1188	9.9813 ± .0230	7.6486 ± .0169	76.6542 ± .1118	50.7666 ± .0863	1
Tautira...	82	20.2622 ± .0530	11.8854 ± .0357	58.7561 ± .1577	10.5098 ± .0310	8.2536 ± .0293	78.4878 ± .1903	51.8780 ± .1320	1
Aiurua...	119	20.3130 ± .0616	11.7000 ± .0294	57.7017 ± .1568	10.2933 ± .0278	7.9403 ± .0225	77.2479 ± .1476	50.7101 ± .1096	1
Oopu...	272	22.8306 ± .0462	12.8949 ± .0222	56.5074 ± .1044	11.5265 ± .0225	8.6662 ± .0175	75.2022 ± .1193	50.5037 ± .0731	1
STANDARD DEVIATION.									
Tuauru...	8	0.5590 ± .0942	0.3708 ± .0625	1.7320 ± .2920	0.3162 ± .0533	0.1984 ± .0334	1.9324 ± .3258	1.6918 ± .2852	0.3308 ± .0558
Ahonu...	145	.9517 ± .0377	.5291 ± .0209	2.3126 ± .0916	.5106 ± .0202	.4215 ± .0167	2.7498 ± .1089	1.8144 ± .0718	1.2092 ± .0477
Papenoo...	336	.9246 ± .0240	.5627 ± .0146	2.3504 ± .0612	.5314 ± .0138	.4555 ± .0119	3.0013 ± .0781	1.9395 ± .0505	1.0172 ± .0262
Faarumai.	19	.8931 ± .0977	.5861 ± .0641	3.3758 ± .3695	.4450 ± .0487	.4059 ± .0444	2.4809 ± .2715	2.0220 ± .2213	0
Tiarei...	15	.7272 ± .0895	.4287 ± .0527	2.9484 ± .3631	.3087 ± .0380	.2828 ± .0348	3.0506 ± .3754	1.3266 ± .1633	.2494 ± .0307
Mahaena.	6	.4713 ± .0918	.2749 ± .0535	1.9791 ± .3854	.2427 ± .0472	.1885 ± .0367	2.1344 ± .4156	.5000 ± .0974	.7454 ± .1451
Paraura...	89	1.0273 ± .0519	.5158 ± .0261	2.1958 ± .1110	.5363 ± .0271	.3915 ± .0198	2.4478 ± .1237	1.8539 ± .0937	.9238 ± .0467
Papeiha...	111	.9884 ± .0448	.5106 ± .0231	2.3439 ± .1061	.5075 ± .0230	.4100 ± .0185	2.7245 ± .1233	1.6741 ± .0758	.0940 ± .0042
Utuufai...	5	.4000 ± .0853	.3919 ± .0836	2.7856 ± .5963	.2939 ± .0626	.3098 ± .0660	4.1665 ± .8887	.8000 ± .1706	0
Haavini...	214	.9250 ± .0301	.4939 ± .0161	2.5764 ± .0840	.4981 ± .0163	.3660 ± .0119	2.4244 ± .0790	1.8718 ± .0610	0
Tautira...	82	.7113 ± .0375	.4796 ± .0252	2.1175 ± .1115	.4166 ± .0219	.3930 ± .0207	2.2554 ± .1346	1.5273 ± .0933	0
Aiurua...	119	.9969 ± .0435	.4738 ± .0208	2.5356 ± .1109	.4490 ± .0196	.3644 ± .0159	2.3877 ± .1044	1.7722 ± .0775	0
Oopu...	272	1.1298 ± .0327	.5420 ± .0157	2.5523 ± .0738	.5497 ± .0159	.4284 ± .0124	2.9172 ± .0844	1.7874 ± .0517	0

those of Haavini are far *longer, wider, and stouter*. In brief, then, a greater average length of the shells in one colony as compared with those of a neighboring valley is not always accompanied by more marked slenderness in proportions, or *vice versa*. A similar lack of consistency might be pointed out for the characters of the aperture, and for the relation of the aperture to the whole shell in length. Finally, the data relating to the columellar tooth provide an additional group of facts supporting the view that differences in hereditary constitution and not differences in environment are accountable for the colonial variations displayed by *rubescens*.

IV. *The relationship between the constituent color-classes of a single valley association is closer than the relationship between any one of them and its counterpart in a neighboring valley.* The statistical data and their graphic representation give the basis for this generalization. In addition, it has been shown that adults of a primary color-class produce offspring of their own kind and of contrasted types as well; certainly, therefore, close genetic bonds exist between snails with differently colored shells, which snails live in one and the same valley.

TABLE 116.—*Partula otaheitana rubescens*. Progressive comparison of valley colonies, in geographical order. Differences in mean values.

Valley.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index.
	Length.	Width.	Proportions.	Length.	Width.	Proportions.		
Tuauru . . .	<i>mm.</i> +1.1603 ± .1436	<i>mm.</i> +0.7666 ± .0932	<i>p. ct.</i> [+0.6379 ± .4328]	<i>mm.</i> +0.5766 ± .0806	<i>mm.</i> +0.5412 ± .0528	<i>p. ct.</i> [+0.3129 ± .4858]	<i>p. ct.</i> [+0.2836 ± .4159]	+1.1559 ± .1038
Ahonu . . .	— .2838 ± .0630	[— .0142 ± .0361]	+ .7311 ± .1557	[+ .0514 ± .0346]	[— .0668 ± .0290]	— .9111 ± .1895	+1.0051 ± .1242	[+ .2019 ± .0770]
Papenoo . . .	[+ .1630 ± .1423]	+ .5554 ± .0930	+2.2889 ± .5296	+ .4352 ± .0716	+ .5059 ± .0650	+1.9206 ± .3994	+1.5731 ± .3209	—1.4828 ± .0371
Faarumai . .	— .5562 ± .1874	[— .2111 ± .1174]	[+ .6421 ± .7326]	— .4899 ± .0874	— .3053 ± .0798	[+ .4526 ± .6555]	[— .9368 ± .3889]	[+ .0667 ± .0434]
Tiarei . . .	—1.4000 ± .1813	— .4800 ± .1014	[+1.7000 ± .7488]	— .4066 ± .0857	— .3333 ± .0715	[— .7333 ± .7922]	+1.7000 ± .2689	+2.6000 ± .2097
Mahaena . .	+ .5712 ± .1491	— .3229 ± .0842	—3.3202 ± .5671	[— .0768 ± .0770]	[+ .1041 ± .0589]	+2.2434 ± .6132	—1.9382 ± .1911	—1.6891 ± .2155
Paraura . . .	+ .9775 ± .0969	+ .4418 ± .0493	[— .4969 ± .2172]	+ .4002 ± .0502	+ .1499 ± .0383	—1.5948 ± .2471	[— .4717 ± .1704]	— .9687 ± .0663
Papeiha . . .	[— .1820 ± .1362]	[— .0656 ± .1226]	[— .4829 ± .8565]	[+ .0699 ± .0944]	— .3207 ± .0970	[—3.1153 ± 1.2688]	[+ .5099 ± .2640]	[— .0089 ± .0060]
Utuufai . . .	[— .2724 ± .1289]	[— .2845 ± .1204]	[— .0551 ± .8516]	— .2787 ± .0915	[+ .1486 ± .0949]	[+2.9542 ± 1.2617]	[— .3334 ± .2562]	0
Haavini . . .	+ .5846 ± .0680	+ .9499 ± .0423	+3.1112 ± .1974	+ .5285 ± .0399	+ .6050 ± .0338	+1.8336 ± .2207	+1.1114 ± .1577	0
Tautira . . .	[+ .0508 ± .0812]	— .1854 ± .0462	—1.0544 ± .2224	— .2165 ± .0416	— .3133 ± .0369	—1.2399 ± .2408	—1.1679 ± .1715	0
Aiurua . . .								
Utuufai . . .								
Oopu <sup>1</sup> . . .	+2.8806 ± .1291	+1.6749 ± .1203	[+ .8074 ± .8497]	+1.2665 ± .0914	+1.1662 ± .0950	[+1.5022 ± 1.2624]	[— .5963 ± .2521]	0

<sup>1</sup>Oopu as compared with Utuufai.

V. *The red and yellow ground-colors seem to bear a Mendelian relation to one another in inheritance, the former being dominant.* Although the final demonstration of Mendelian heredity in these characters can not be given without experimental evidence, the facts in most cases are in essential accord with such an interpretation. Where there are sufficient data, the relative numbers of the two classes are in equilibrium. The heredity of ground-color is alternative in all cases. Proceeding on the assumption that red color is dominant to yellow, an analysis of the group displaying the latter character gives the means for testing the correspondence between expectation and empirical observation in the case of the alternative group, with general agreement as the result.

VI. *Combining the statistics for the several colonies, a collective description of the primary variety is obtained which serves for a precise comparison of P. otaheitana rubescens with other major divisions of the species.* There are two modes of combining the colonial statistics so as to derive this collective description, and each mode has

its special value for a particular biological problem. In the first place, all individuals may be united into a single series, when the figures for the mean value and standard deviation will define the variety as it occurs in the whole area of its occupation. In this case, colonies which are numerous represented in the collections will affect the general average far more than series that comprise only a few snails or a single specimen. Yet the valley collections were made during approximately equal lengths of time, and the varying abundance of *rubescens* in the several associations indicates the biological fact that shells of different sizes and shapes do not occur with equal frequency. Furthermore, errors due to inequalities in the number of hours devoted to field-collecting balance one another to some extent when all of the series are grouped together. Hence, from one point of view, the description of the variety on the basis of all specimens grouped together is the best. The figures are given in table 118.

TABLE 118.—*Partula otaheitana rubescens*. Summary description.

MEAN VALUE.								
	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth. index.
	Length.	Width.	Proportions.	Length.	Width.	Proportions.		
Combined series, all valleys.....	<i>mm.</i> 20.6411 ± .0266	<i>mm.</i> 11.5942 ± .0154	<i>p. ct.</i> 56.1709 ± .0478	<i>mm.</i> 10.4608 ± .0134	<i>mm.</i> 7.9475 ± .0100	<i>p. ct.</i> 76.0105 ± .0539	<i>p. ct.</i> 50.6772 ± .0337	1.5578 ± .0171
Combined series, 13 tabulated valleys..	20.6388 ± .0267	11.5932 ± .0155	56.1650 ± .0478	10.4606 ± .0134	7.9470 ± .0100	76.0060 ± .0539	50.6710 ± .0337	1.5598 ± .0172
Average of all valley types.....	19.8452	11.3392	57.0354	10.2033	7.7924	76.4789	51.3247	1.1838
Average of 13 tabulated valley types..	20.1510	11.4312	56.7029	10.2122	7.8356	76.2401	50.9880	1.5083
STANDARD DEVIATION.								
Combined series, all valleys.....	1.4900 ± .0188	0.8643 ± .0109	2.6769 ± .0338	0.7491 ± .0095	0.5618 ± .0071	3.0180 ± .0381	1.8865 ± .0238	0.9603 ± .0121
Combined series, 13 tabulated valleys..	1.4905 ± .0189	.8659 ± .0109	2.6743 ± .0338	.7493 ± .0095	.5622 ± .0071	3.0154 ± .0381	1.8862 ± .0238	.9619 ± .0122
Average of all valley types.....	.6503	.3755	2.0447	.3225	.2842	2.1485	1.2823	.2817
Average of 13 tabulated valley types..	.6756	.4738	2.4466	.4312	.3550	2.6671	1.5832	.3515

In the same tabulation, the several mean values and standard deviations are averaged, each colony being accorded the same weight as another, irrespective of the number of individuals giving the basis for any single constant. Thus, the Oopu colony includes 272 shells, while only a single specimen was obtained in Apirimaue. The summary gives the average of the typical conditions for the several valleys—for all 18, and for the 13 which have been analyzed in detail. When the facts are treated in this manner the figure for a given character (as for example, shell length) differs from the average for the series taken as a whole; in this particular instance the reason is that the colonies which are numerous represented in the collections have larger shells than those which include only a few

TABLE 117. *Partula otaheitana rubescens*. Progressive variation of the colonies in range and mean value. (Whole series, full lines; yellow class, repeated dashes; red class, dot and line.)

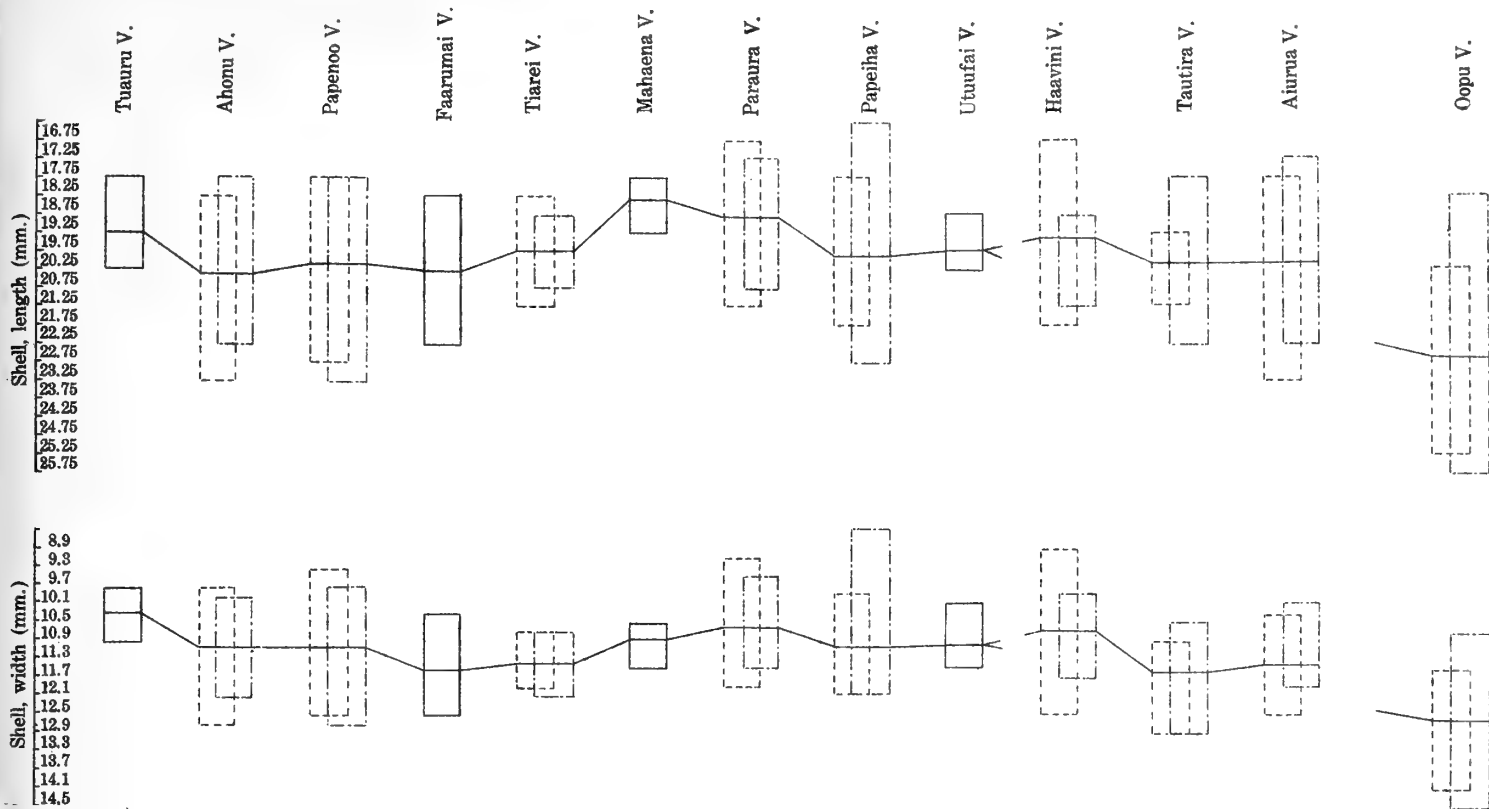
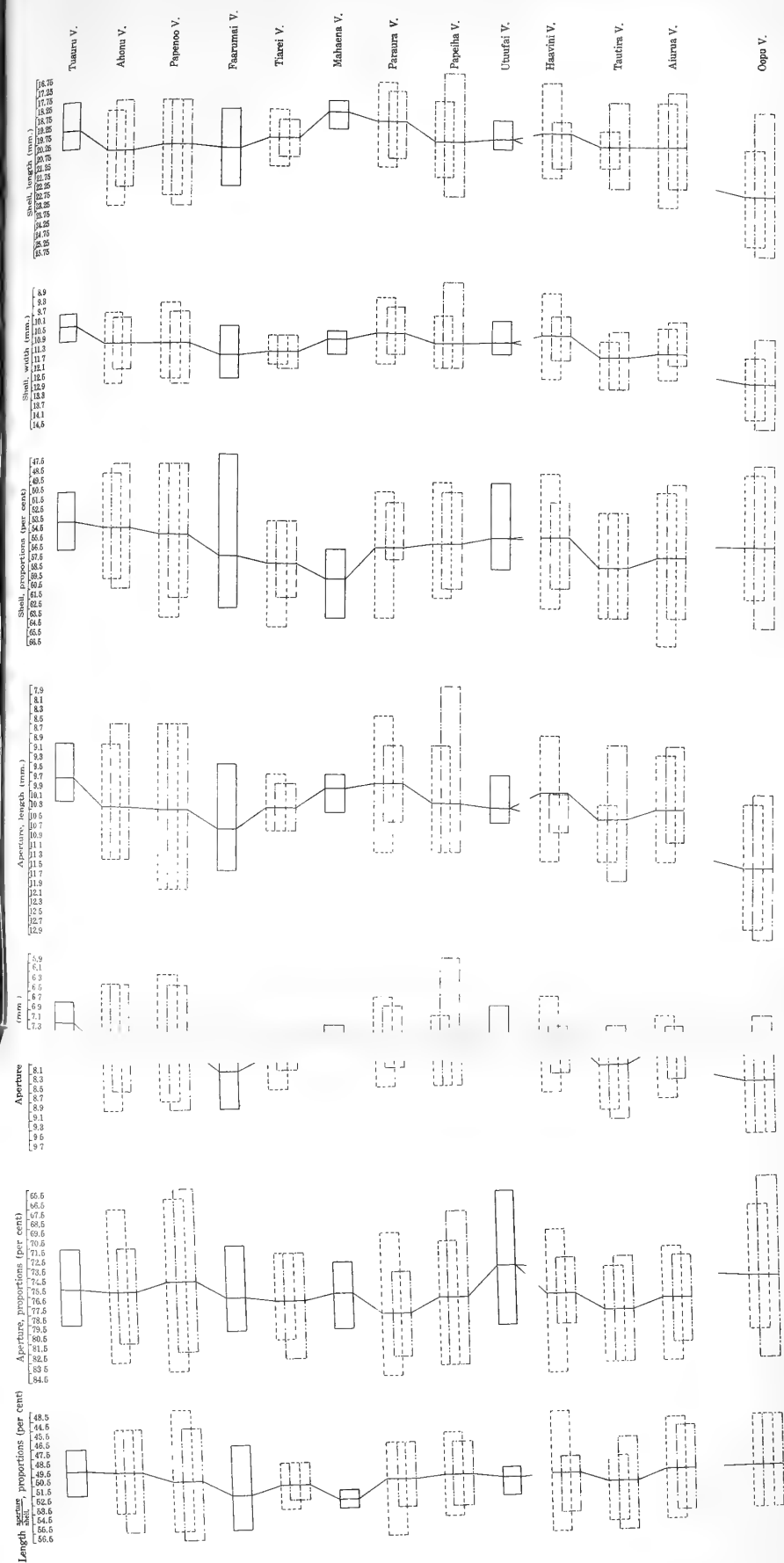


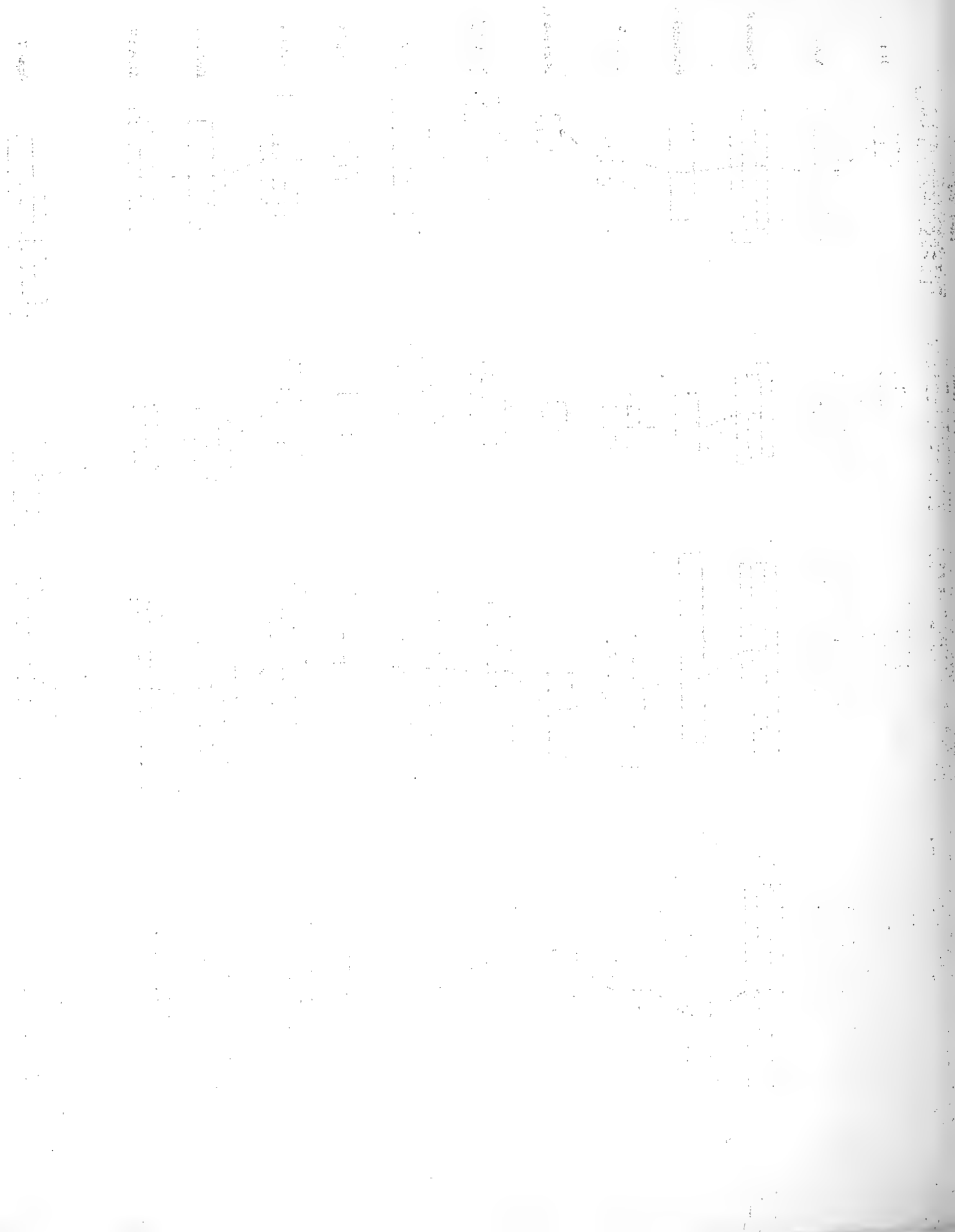




TABLE 117. *Partula otaheitana rubescens*. Progressive variation of the colonies in range and mean value. (Whole series, full lines; yellow class, repeated dashes; red class, dot and line.)



the ... ..  
to ... ..



individuals. Yet the latter represent so many *valley types*, and it is interesting to ascertain what the general condition of the variety is, when defined on the basis of such valley types taken as genetic entities, aside from the numerical abundance of their representatives.

### PARTULA OTAHEITANA AFFINIS Pease.

#### GENERAL CONSIDERATIONS.

Hitherto in dealing with the primary subdivisions of the present species we have followed a regular geographical order, beginning with *P. otaheitana otaheitana* of Fautaua Valley, which merges into *P. o. amabilis* of a short northern series of valleys; immediately beyond the latter's range *P. o. rubescens* appears, and extends widely around Tahiti nui and Taiarapu without varying sufficiently in major characteristics to justify the establishment of secondary varieties with distinctive names. We must now return to the northern sector of Tahiti nui, for the primary subdivision *affinis*, now to be taken up, begins its range just beyond the territory of *amabilis*, and accompanies *rubescens* in nearly all of the valleys of the eastern sector and of Taiarapu.

The variety *affinis* presents new features of distribution and intrinsic variation, as well as many that have been encountered in the study of the earlier-described divisions. It is greatly diversified as compared with *rubescens*, although all of its variants agree in the distinguishing characters of the primary variety, which features are traceable to those of the common ancestral stock of the whole species, now best represented by *P. o. otaheitana*. The subdivision as a whole is so clearly demarcated that it was described by Pease as an independent species, *Partula affinis*; furthermore, one of its subordinate color-forms has been given the status of a major variety, viz, *dubia*. But a closer study of the snails and of their inter-relationships leads inevitably to the conclusion that *affinis* is a variety of *P. otaheitana*, although its internal differentiation equals that of such a distinct species as *Partula clara*.

The range of *P. o. affinis*, taken as a whole, includes the entire area inhabited by *rubescens*—its very antithesis in most respects—while it also comprises valleys in Taiarapu which lack *rubescens*, but which bear members of still another primary variety, *sinistrorsa*. Specifically, *affinis* spreads from Tuauru Valley throughout the eastern sector and throughout Taiarapu; its range ceases in Tahiti nui with the same valleys—Oopu and Apirimaue—that constitute the limits of the habitat of *rubescens*. It is noteworthy that these two sharply contrasted primary types occupy in common so many valleys situated in different parts of the whole island. The essential point, which becomes increasingly clear, is that one and the same environmental situation could scarcely produce two antithetic types in and by itself.

The original description of *Partula affinis* by Pease (Amer. Jour. Conch., 1867) is as follows:

"Slightly elongately ovate, rather solid, compressly umbilicate, dextral,<sup>1</sup> finely, roughly, and irregularly striated longitudinally, transversely very minutely striate, sutures

<sup>1</sup>In the Latin description, also, "Anfr. 5, plano-convexis, ultimus  $\frac{2}{3}$  longitudinis testæ subæquans."

impressed, sometimes faintly marginated; lip narrowly thickened, occasionally connected with the columella by a thin callosity; columella dentate. Color light or dark chestnut brown, sometimes striped with darker or wholly of a straw color.

"*Var.* Encircled with three dark reddish brown bands, on middle of last whorl, at the umbilicus, and just beneath the suture.

"*Obs.* The above species is allied to *P. otaheitana*. It is, however, smaller and less elongate.

"*Dim.* Long. 16, diam. 9 mill. Hab. Tahiti."

In his invaluable monograph, Garrett gives the following account of *affinis*:

"Pease's *affinis*, which can not be separated from some of the small abbreviated forms of *Otaheitana*, occurs in greater or less abundance in all the valleys from Haona as far as the southeast end of Taïarapu peninsula, and round the opposite coast as far as Papiéri [Papeari] on the southwest of Tahiti proper. In Papinoo [Papenoo] I discovered a large colony of *affinis*, many of which had the pinky flesh-colored lip and sinistral form of *Otaheitana*. Far up in the same valley, though common, none but dextral forms were found, and out of thousands taken in the other valleys, not one sinistral example occurred to my notice. In a valley several miles from Papinoo I found a small colony of *affinis*, which were marked by three transverse reddish chestnut bands like *lignaria*. And, most singular, no other banded specimens of *affinis* occurred to my notice in any other part of the island. It is the variety *dubia* Pse., and by Carpenter erroneously referred to *varia*."

In the detailed analysis of the variation and distribution of *affinis*, as this will be presented in the following pages, it will be made evident that, in the main, the situation so clearly and precisely described by Garrett exists to-day, but it will also be demonstrated that certain changes have taken place since Garrett's observations were made. Some of these changes are sufficiently important to be noted at this juncture.

Garrett speaks of a large (local) colony of *affinis* in Papenoo Valley whose members were sinistral and were colored in certain respects like *rubescens*; in my own collections only 7 snails out of 160 adults of this variety were reversed, even though three separate journeys were made into this valley in as many different years; these, however, were brown, not yellow or red. In his very next sentence he says that not a single sinistral example was secured elsewhere, out of thousands collected. In my personal experience, such individuals were discovered in *six other valleys*, in widely separated parts of the whole range. Again, Garrett locates a banded variety, which apparently was named *P. dubia* by Pease, in a valley "several miles from Papenoo," adding that no other banded specimens were found elsewhere in the island. In a personal letter to Hartman, he specifies the exact distance of 8 miles beyond Papenoo for the locus of *dubia* which my own observations have confirmed. But it is significant, in view of what Garrett says, that banded forms of one kind or another were collected by me in *twenty-one* different valleys, located in various parts of the whole range! As we can not believe that Garrett was unacquainted with the snails of many, even if not of all, of these valleys, it is evident that a notable development of banded types has occurred since his day, even as in the case of occasional sinistral individuals.

A further preliminary word regarding *dubia* is necessary. In the literature there is some confusion of *affinis dubia* Pease, with certain forms of *Partula faba* taken in the island of Tahaa, and named *dubia* by Garrett in manuscript; the name should be reserved for the subordinate form of *Partula otaheitana affinis*. Pilsbry, it is true, regards this distinctly banded type as coequal with *affinis*, an opinion in which I can not concur for reasons which will appear in the detailed description.

Hartman, in my judgment, is entirely in error in uniting *affinis* with *lignaria*; the latter primary variety, as we shall see, is located far away from the territory of the former, and its representatives differ fundamentally in size, shape, strigation, and banding when this occurs. With regard to other synonyms which have been given as specific names to peculiar individuals, such as *bacca* and possibly *nitens*, it may be said that they prove to be of no real taxonomic value when a survey is made of all of the colonies of *affinis* with all of their variations.

In earlier pages it has been stated that this primary variety, taken as a whole, is referable to an ancestral stock like the composite *P. otaheitana otaheitana* of Fautaua Valley, because its distinctive peculiarities, here unmixed with others, are displayed by some of the members of the latter subdivision. Specifically, what may be called the general unit-characters of *affinis* are as follows:

*Coil*: Dextral predominating, sinistral by occasional mutation.

*Color*: Various shades of light and dark brown, faintly reddish only in certain sharply restricted colonies. Sometimes strigated. Banded patterns of diverse types, locally restricted. Apex almost invariably like the larger whorls in color.

*Surface*: Strigated both transversely and longitudinally; never as smooth as *rubescens*.

In a word, the diagnostic qualities of *affinis* are precisely those which *rubescens* lacks, and *vice versa*, with rare exceptions in the case of reversed coil and reddish color.

The absolute and relative numbers of *P. o. affinis* in the valleys of its entire range have been given in table 56; the variations in numerical abundance possess much significance, but it is unnecessary to repeat the pertinent discussions of earlier pages. Additional details regarding the make-up of the several colonies are given in table 119. While the figures for some of the valleys are doubtless misleading on account of the small numbers involved, yet enough colonies are fully represented in the collections to provide the basis for certain definite conclusions. It is certain that there is considerable variation, colony by colony, in the proportionate numbers of dextral and sinistral snails, and in the relative abundance of the unbanded and banded color-forms. Further data as to variation in the relative numbers of subordinate color-forms do not appear in this table, but they will receive due consideration later.

Proceeding one step further, we may array the several colonies in groups of a secondary order, on the basis of subordinate characters. In most cases it requires very close study and comparison of the several localized associations in order to discern any differentia of real value; when discovered, they are small of necessity, but they are fully as significant as the wider differences exhibited by the several associations of *P. clara* and *P. nodosa*, and by the colonies of the *otaheitana crassa* series, later to be described. One of the subdivisions of *affinis*, viz, *erythræa*, is so

distinct in morphological characters and so separated geographically that a secondary varietal term is employed for the purpose of accurate and concise definition. This procedure implies that such a group stands more apart genetically than do the several colonies that are not thus distinguished.

TABLE 119.—*Partula otaheitana affinis*. Census of the collections.

Series and valley.	No. of adults.	Dextral.		Sinistral.		Per cent of dextral.		Per cent of sinistral.	
		Plain.	Banded.	Plain.	Banded.	Plain.	Banded.	Plain.	Banded.
Northern:									
Tuauru.....	366	267	96	3	..	72.9	26.2	0.8	....
Ahonu.....	149	143	3	3	..	95.9	2.0	2.0	....
Faaripoo.....	310	304	6	..	..	98.0	1.9	.....	....
Papenoo.....	160	153	..	7	..	95.6	....	4.3	....
<i>erythræa</i> :									
Farapa.....	591	451	140	..	..	76.3	23.6	.....	....
Eastern:									
Faarumai.....	334	321	13	..	..	96.1	3.8	.....	....
Tiarei.....	151	135	16	..	..	89.4	10.5	.....	....
Mahaena.....	141	132	5	3	1	93.6	3.5	2.1	0.7
Vahii.....	409	406	3	..	..	99.2	0.7	.....	....
Paraura.....	579	466	113	..	..	80.4	19.5	.....	....
Faatautia.....	12	9	3	..	..	75.0	25.0	.....	....
Papeiha.....	163	149	14	..	..	91.4	8.5	.....	....
Utufai.....	342	270	72	..	..	78.9	21.0	.....	....
Faone.....	592	520	72	..	..	87.8	12.1	.....	....
Northern Taiarapu:									
Tehoro.....	305	249	<sup>1</sup> [56]	..	..	81.6	<sup>1</sup> [18.3]	.....	....
Haavini.....	59	51	<sup>1</sup> [5]	3	..	86.4	<sup>1</sup> [8.5]	5.0	....
General Taiarapu:									
Tautira.....	207	205	2	..	..	99.0	0.9	.....	....
Aionifaa.....	14	14	..	..	..	100	....	.....	....
Aiurua.....	100	100	..	..	..	100	....	.....	....
Vaiau.....	16	11	..	5	..	68.7	..	31.2	....
Hototunu.....	45	39	6	..	..	86.6	13.3	.....	....
Vaiaaia.....	6	4	1	1	..	66.6	16.6	.....	....
Aiavaro.....	0	..	..	..	..	..	..	.....	....
Vavii.....	6	5	1	..	..	83.3	16.6	.....	....
Vaipoe.....	69	40	29	..	..	57.9	42.0	.....	....
Haoma.....	44	41	3	..	..	93.1	6.8	.....	....
Papeari colonies:									
Oopu.....	36	33	3	..	..	91.6	8.3	.....	....
Apirimaue.....	6	6	..	..	..	100	....	.....	....
Total.....	5,212	4,524	662	25	1	86.79	12.70	0.49	0.02

<sup>1</sup>Bicolored, not striped.

A brief résumé of the general situation will aid in comprehending the detailed analysis of the several colonies of this variety. In the northernmost part of the range the shells are typical and require no special qualifying term, although the banded specimens differ somewhat from those found elsewhere. The colonies of this area, which extends from Tuauru to Papenoo Valleys inclusive, are called merely the "northern series." A unique association is found in the next valley, Farapa, and in that restricted area only; it is named *erythræa* on account of the red-dish color that is displayed by the majority of the shells. From Faarumai to Faone, that is, throughout the rest of the eastern sector, the shells are much like those of the northern series, but among them are representatives of the three-banded color-type named *dubia* by Pease and regarded by Pilsbry as a subspecies of *otaheitana*; it is really only a color-form, to be distinguished orthographically as *dubia*; in

addition, a type with broad zonal stripes makes its appearance, to be distinguished as the color-form *zonata*. Thus the colonies of the "eastern series" are characterized by the occurrence of *dubia* and *zonata* color-forms, in varying numbers. Proceeding out into the peninsula along the northern side, in Tehoro and Haavini Valleys one finds a new kind of particolored shell in which the colors are different on the two sides of the morphological sagittal plane; the special name given on this account is *anomala*, but the novel color-form does not predominate to such a degree that the term may be used as a subvarietal designation. Throughout the rest of Taiarapu the shells are little differentiated and resemble those of the eastern series especially; the colonies here are grouped as the "general Taiarapu series." Finally in Oopu and Apirimaue, there are again typical *affinis* associations, to be called the Papeari colonies, from their district.

#### THE NORTHERN SERIES—TUAURU TO PAPENOO VALLEYS.

##### TUAURU VALLEY.

The Tuauru colony, at the northward limit of the whole range, is large and flourishing and is sharply contrasted with the last colony of *P. otaheitana amabilis* in the near-by valley of Ururoa. Out of 366 adult shells, all but 3 are dextral, whereas in the Ururoa *amabilis* association only one dextral individual was found in a series of 345 adults. The dimensions of the aperture and its proportions are also distinctively different, but in coloration there is less contrast.

Unbanded or "plain" shells predominate (73 per cent), and they are divisible into "light" and "dark" groups, which occur in the general proportion of 2 to 5. Shells of the first group (plate 28, figs. 24 to 27) are usually marked with darker strigations upon a yellowish-brown background, although many are virtually uniform in coloration without distinct strigation. The darker shells (plate 28, figs. 28 to 34) grade from heavily strigated to solid seal-brown types. The sinistral shells (plate 28, figs. 35 and 36) are unbanded. The banded shells (plate 28, figs. 37 to 41) all display a "median" stripe and sometimes a basal clouding as well. The median band is usually narrow, but sometimes it is doubled in width. In one specimen only (plate 28, fig. 42) the band is nearly confluent with the basal marking in such a way as to produce a bicolored appearance, thus simulating, but not equaling, the distinctive form of coloration termed *anomala* found in the far-distant valleys of Tehoro and Haavini.

Wide variations in size and shape are displayed by the shells employed as illustrations. The statistical data (table 120) prove that the lighter plain group differs somewhat from the darker series; the differences are significant in shell width, shell proportions, possibly in aperture width, surely in the relations of the aperture to the whole shell and in tooth development. The banded shells agree closely with the others, saving only in the growth of the pillar-tooth. In general, the striped shells are more variable than those of the contrasted class.

The plain sinistral shells as compared with the whole series of dextral individuals, or with only their plain division, are about the same in length, but are stouter on the whole and their apertures are larger, absolutely and relatively. At first it

might seem that these three shells represent stragglers from the *Ururoa amabilis* colony, but their individual measurements are well within the ranges of the characters displayed by the dextral series, in the several instances, while the relationship thus indicated is finally established by the fact that two young, borne by one of them, are dextral and light-brown in color; the *Ururoa* snails breed true to their sinistrality. Hence these snails are to be regarded as sporadic mutants from the general stock.

TABLE 120.—*Partula otaheitana affinis*. Tuauru Valley.

MEAN VALUE.									
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
Plain, light. dark.	78	<i>mm.</i> 17.4000 ± .0660	<i>mm.</i> 10.3795 ± .0311	<i>p. ct.</i> 59.6538 ± .1604	<i>mm.</i> 9.3538 ± .0355	<i>mm.</i> 7.3384 ± .0249	<i>p. ct.</i> 78.4487 ± .2135	<i>p. ct.</i> 53.7692 ± .1392	3.1410 ± .0661
	184	17.3946 ± .0399	10.2945 ± .0224	59.0978 ± .0997	9.3119 ± .0245	7.2848 ± .0180	78.2653 ± .1320	53.3641 ± .0950	2.7884 ± .0302
Plain, all . . Banded . . .	262	17.3962 ± .0336	10.3198 ± .0183	59.2633 ± .0854	9.3252 ± .0202	7.3008 ± .0148	78.3206 ± .1125	53.4847 ± .0790	2.8914 ± .0294
	92	17.3391 ± .0507	10.3326 ± .0276	59.4891 ± .1611	9.2978 ± .0302	7.3326 ± .0224	78.5761 ± .1636	53.5217 ± .1269	2.7912 ± .0420
All . . . . .	354	17.3814 ± .0282	10.3232 ± .0153	59.3220 ± .0759	9.3181 ± .0169	7.3091 ± .0125	78.3870 ± .0936	53.4944 ± .0671	2.8650 ± .0249
Sin., plain..	3	17.3500 ± .2754	10.5666 ± .1468	60.8333 ± .1836	9.6333 ± .0734	7.6333 ± .0368	79.5000 ± .5507	55.1666 ± .4856	3.0000 ± .0
STANDARD DEVIATION.									
Plain, light. dark.	78	0.8639 ± .0466	0.4080 ± .0220	2.1005 ± .1134	0.4654 ± .0251	0.3267 ± .0174	2.7960 ± .1509	1.8234 ± .0984	0.8656 ± .0467
	184	.7818 ± .0282	.4583 ± .0158	2.0057 ± .0705	.4922 ± .0173	.3674 ± .0127	2.6548 ± .0933	1.9133 ± .0671	.6152 ± .0213
Plain, all . . Banded . . .	262	.8069 ± .0237	.4399 ± .0128	2.0502 ± .0603	.4847 ± .0143	.3566 ± .0104	2.6990 ± .0795	1.8961 ± .0558	.7133 ± .0208
	92	.7210 ± .0358	.3926 ± .0195	2.2912 ± .1139	.4298 ± .0213	.3193 ± .0159	2.3274 ± .1156	1.8057 ± .0857	.6108 ± .0297
All . . . . .	354	.7860 ± .0199	.4281 ± .0108	2.1178 ± .0537	.4712 ± .0120	.3475 ± .0088	2.6100 ± .0662	1.8730 ± .0474	.7029 ± .0176
Sin., plain..	3	.7071 ± .1947	.3771 ± .1038	.4714 ± .1298	.1886 ± .0519	.0946 ± .0260	1.4142 ± .3894	1.2470 ± .3434	.0

The statistics of fecundity (table 121) show an average productivity for the season of collection. The data of heredity (table 122) for the dextral snails prove that the several subdivisions breed their own respective kinds in the majority of cases, but also produce young of the other classes. The summary gives almost exactly the same proportionate numbers in the color-classes of the young and of the gravid adults, which is a remarkable and unusual agreement.

Of the three sinistral adults, one was barren, another contained a single egg, and the third (as noted above) bore two light-brown, plain, and dextral young. Obviously the reversed individuals are genetically related to the prevalent stock.

#### AHONU VALLEY.

The collection of *affinis* from Ahonu comprised fewer numbers than that just described, but still enough to provide definite statistics for inter-valley comparisons, while its intrinsic composition is interesting on its own account. It is noteworthy that *rubescens* exists in large relative numbers in this area, whereas very few were found in Tuauru. Only 3 out of 149 adults were *dextral and banded*, while an equal number were *sinistral and plain*, thus giving a composition that is markedly different from that of the earlier-described colony. Like the majority of the banded speci-



mens of Tuauru, those of Ahonu display a distinct median stripe, and usually an ill-defined basal marking. The plain shells (plate 28, figs. 43 to 45) are far less strigated and hence much more even in coloration, while their tints are richer than before; in one specimen (fig. 45) a rose-brown spine occurs. The statistics as given in table 123 show that the members of this colony are smaller on the whole than in Tuauru. The figures for the banded dextral and the plain reversed shells must not be given too much weight, in view of the small numbers concerned, but in the case of the first-named class it is clear that the departures from the conditions of the more abundant plain stock are not in the directions taken by the banded group in Tuauru.

TABLE 121.—*Partula otaheitana affinis*. Tuauru Valley. Fecundity.

Series.	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.
Dextral, plain, light...	77	63	81.8	34	74	108	1.7	1.4
dark...	189	153	80.9	103	178	281	1.8	1.5
Dextral, plain.....	266	216	81.2	137	252	389	1.8	1.5
banded.....	76	54	71.0	49	58	107	1.9	1.4
Dextral, all.....	342	270	78.9	186	310	496	1.8	1.4

TABLE 122.—*Partula otaheitana affinis*, Tuauru Valley. Heredity.

	Young, plain.		Young, banded.	Total.	Summary.		Total.
	Light.	Dark.			Young, plain.	Young, banded.	
Adults:							
Plain {light.....	51	16	7	74	222	30	252
{dark.....	75	80	23	178			
Banded.....	13	7	38	58	20	38	58
Total.....	139	103	68	310	242	68	310

TABLE 123.—*Partula otaheitana affinis*. Ahonu Valley.

MEAN VALUE.									
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index. <sup>1</sup>
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
Dex., plain....	140	mm. 17.0150 ± .0472	mm. 10.0628 ± .0281	p. ct. 59.0214 ± .1135	mm. 9.0200 ± .0298	mm. 6.9328 ± .0230	p. ct. 76.7571 ± .1429	p. ct. 52.8500 ± .1079	2.4930 ± .0765
banded...	3	16.9500 ± .3350	9.9666 ± .1468	58.5000 ± .5507	8.7666 ± .2407	6.8333 ± .1468	77.5000 ± .5507	51.5000 ± .8412	1.6666 ± .3668
Dex., all.....	143	17.0136 ± .0469	10.0608 ± .0277	59.0105 ± .1114	9.0147 ± .0297	6.9308 ± .0227	76.7727 ± .1406	52.8217 ± .1077	2.4759 ± .0756
Sin., plain, all..	3	17.4500 ± .1652	10.5667 ± .1600	60.5000 ± .5507	9.1000 ± .1682	7.3667 ± .1324	80.8333 ± .8002	51.8333 ± .4856	2.0000 ± .3179
STANDARD DEVIATION.									
Dex., plain....	140	0.8281 ± .0334	0.4937 ± .0198	1.9909 ± .0802	0.5225 ± .0210	0.4032 ± .0163	2.5082 ± .1010	1.8933 ± .0763	1.3517 ± .0541
banded...	3	.8602 ± .2369	.3771 ± .1038	1.4142 ± .3894	.6182 ± .1702	.3771 ± .1038	1.4142 ± .3894	2.1602 ± .5948	.9421 ± .2592
Dex., all.....	143	.8319 ± .0332	.4918 ± .0196	1.9759 ± .0788	.5259 ± .0210	.4029 ± .0161	2.4924 ± .0994	1.9091 ± .0762	1.3497 ± .0534
Sin., plain, all..	3	.4242 ± .1168	.4109 ± .1131	1.4142 ± .3894	.4320 ± .1189	.3399 ± .0936	2.0548 ± .5658	1.2471 ± .3434	.8165 ± .2248

<sup>1</sup>Numbers for the several groups are 142, 3, 145, 3.

In fecundity (table 124) the dextral classes exhibit the expected average. Unfortunately the reversed adults bore no young snails sufficiently advanced to be interesting. The light and dark classes produced contrasted young as well as their own kind (table 124), while all four of the embryonic snails from banded adults were apparently plain, and light in color. Possibly the production of markings is delayed in this colony. It must not be supposed that the adults of this class are really products of the more numerous banded stock of Tuauru, for aside from topographical difficulties involved, a single striped adolescent, well advanced, was found here; this individual must have been produced by an adult residing in Ahonu. Again, as regards the few sinistral snails, an origin elsewhere is not probable; even though all of the young of dextral adults were direct in their coil, and although the several adults themselves do not provide data on heredity, yet a single small sinistral adolescent collected in Ahonu gives positive proof that such individuals are produced in this valley, although infrequently.

TABLE 124.—*Partula otaheitana affinis*. Ahonu Valley.

FECUNDITY.									HEREDITY.				
Series.	Rec-ords.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.		Young, plain.		Young, banded.	Total.
										Light.	Dark.		
Dex., plain . . . banded.	137 3	99 3	72.2 100	52 1	125 4	177 5	1.79 1.66	1.29 1.66	Adults: Plain: Light . . . Dark . . . Banded . . . Total . . . . .	37	29	..	66 59 } 125 4
Dex., all . . . . .	140	102	72.9	53	129	182	1.78	1.30		23	36	..	
										4	..	..	
Sin., plain . . . .	3	2	66.6	2	0	2	1.0	0.6		64	65	0	
										129			

## FAARIPOO VALLEY.

In this narrow gully, not far from Papenoo, cleft in the triangular land-mass to the west of that great valley, a flourishing colony of *affinis* was found, although the associated *rubescens* was very sparsely represented, as noted earlier. The general composition of this colony is much like that of Tuauru, with two exceptions: reversed individuals are absent and banded shells are few, as in Ahonu. The last-named (plate 28, figs. 48 and 49) display three well-marked stripes, viz, the basal, the median, and the subsutural, the last of which was rarely exhibited by shells of the north. The light and dark classes (plate 28, figs. 46 and 47, unusual types) differ distinctly in several of the statistical characters (table 125). The members of the small banded group agree sometimes with the one and sometimes with the other class of unstriped shells.

The fecundity of all classes is high (table 126), with substantial agreement. In the matter of heredity (table 126) it is interesting to find that the plain and banded groups breed true to their respective types. Yet here, too, the latter are to be regarded as genetically allied to the former, and not as stragglers from near-by valleys. Ahonu to the west is well separated topographically, while the next valley to the east where banded snails occur is Farapa, on the other side of Papenoo, in which none of this type were taken.

TABLE 125.—*Partula otaheitana affinis*. Faaripoo Valley.

MEAN VALUE.									
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index. <sup>1</sup>
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
Plain, light.. dark..	88	<i>mm.</i> 16.5602 ± .0531	<i>mm.</i> 9.8863 ± .0296	<i>p. ct.</i> 59.5113 ± .1442	<i>mm.</i> 8.9545 ± .0300	<i>mm.</i> 6.8386 ± .0217	<i>p. ct.</i> 76.2955 ± .1773	<i>p. ct.</i> 53.8863 ± .1247	2.1819 ± .0664
	214	16.7939 ± .0326	9.9009 ± .0192	58.8691 ± .0938	8.9799 ± .0191	6.8037 ± .0162	75.5842 ± .1240	53.3925 ± .0859	2.0602 ± .0542
Plain, all... Banded....	302	16.7256 ± .0281	9.8967 ± .0161	59.0563 ± .0768	8.9722 ± .0161	6.8139 ± .0131	75.7914 ± .1027	53.5364 ± .0714	2.0954 ± .0435
	6	16.7500 ± .0778	10.0000 ± .1376	59.3333 ± .6242	8.8666 ± .1026	6.8666 ± .0796	77.8333 ± .3784	52.3334 ± .4878	1.5000 ± .1376
All.....	308	16.7263 ± .0276	9.8987 ± .0160	59.0617 ± .0764	8.9701 ± .0167	6.8149 ± .0129	75.8312 ± .1015	53.5130 ± .0710	2.0839 ± .0429
STANDARD DEVIATION.									
Plain, light.. dark..	88	0.7396 ± .0375	0.4121 ± .0209	2.0055 ± .1020	0.4175 ± .0212	0.3021 ± .0153	2.4641 ± .1253	1.7349 ± .0881	0.9238 ± .0469
	214	.7082 ± .0230	.4162 ± .0136	2.0345 ± .0663	.4151 ± .0141	.3521 ± .0114	2.6901 ± .0876	1.8627 ± .0607	1.1984 ± .0383
Plain, all... Banded....	302	.7253 ± .0198	.4150 ± .0114	1.9805 ± .0542	.4161 ± .0114	.3387 ± .0093	2.6459 ± .0897	1.8401 ± .0505	1.1257 ± .0307
	6	.2828 ± .0550	.5000 ± .0974	2.2669 ± .4413	.3727 ± .0725	.2896 ± .0562	1.3744 ± .2675	1.7717 ± .3449	.5000 ± .0973
All.....	308	.7193 ± .0195	.4171 ± .0113	1.9868 ± .0540	.4356 ± .0118	.3371 ± .0091	2.6422 ± .0718	1.8463 ± .0502	1.1214 ± .0303

<sup>1</sup>Numbers for the several groups are 88, 216, 304, 6; 310.TABLE 126.—*Partula otaheitana affinis*. Faaripoo Valley.

FECUNDITY.									HEREDITY.							
Series.	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.		Young, plain.		Young, banded.	Total.			
										Light.	Dark.					
Plain, light..	87	72	82.7	119	63	182	2.52	2.09	Adults: Plain: Light... Dark... Banded...							
dark..	209	185	88.5	291	156	447	2.41	2.14								
Banded.....	5	5	100	7	5	12	2.40	2.40		36	27	..	63			
										35	121	..	156			
All.....	301	262	87.0	417	224	641	2.44	2.13								
									Total.....	71	148	5	224			
									219							

## PAPENOO VALLEY.

The representatives of *P. otaheitana affinis* from this valley are intrinsically interesting, especially by contrast with associations in the valleys on either side; but Garrett's description of the *affinis* colony in Papenoo as it existed in his time greatly enhances the value of the present collection. The essential points stated by Garrett, already quoted, are that he found a "large colony" of sinistral *affinis* whose members displayed some of the color-characters as well as the coil of *rubescens*, the dominant type of this valley, and also that "far up in the same valley, though common, none but dextral forms were found."

My own experience differs from that of Garrett. As explained in full in connection with the description of *rubescens*, three journeys were made into Papenoo and the collections represent three consecutive subsidiary regions of the whole area. The actual numbers taken are given in table 127. It appears that no sinistral speci-

mens were found in the lower valley, where dextral individuals are few and *rubescens* abounds, and that reversed snails increased in numbers in passing further inland. My own sinistral specimens are entirely typical brown *affinis*, and do *not* exhibit the color-characters of *rubescens*. How far inland their kind extends, I do not know; quite probably they decrease in numbers when the central basin is reached, but certainly they do not *now* exist as a large and flourishing colony in the outward part of the whole habitable area, so far as my threefold experience goes.

TABLE 127.—*Partula otaheitana affinis*. Papenoo Valley.

Area.	Dextral.		Sinistral.		Per cent of adult otaheitana population.	
	Adults.	Adolescents.	Adults.	Adolescents.	Dextral.	Sinistral.
Lower (1906) . . . . .	5	3	0	0	6.66	0
Middle (1908) . . . . .	57	7	2	1	38.25	1.34
Upper (1909) . . . . .	91	19	5	0	32.73	1.79

One further matter needs to be discussed at this point, namely, the statement by Garrett that *Partula stolidia* Pease occurs in this valley at a point "about two miles up" lurking among fern roots. This species is referred by Pilsbry to *P. compressa* "Pfeiffer" Reeve. In spite of prolonged search, no specimens were found that conformed to the descriptions of any of these writers. Certain of the *affinis* shells, it is true, are much compressed in the last whorl, but such shells fall far short of the length given by Garrett. It may be that such examples are really abbreviated relatives of the shells named by Pease as *stolidia*; if so, then the type so distinguished is only a modified *affinis*, for my own specimens certainly belong to the latter primary variety.

TABLE 128.—*Partula otaheitana affinis*. Papenoo Valley.

MEAN VALUE.									
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index. <sup>1</sup>
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
Dex., 1908. . . . .	55	<i>mm.</i> 16.6918 ± .0734	<i>mm.</i> 9.7145 ± .0368	<i>p. ct.</i> 57.9546 ± .2246	<i>mm.</i> 8.9981 ± .0376	<i>mm.</i> 6.6200 ± .0317	<i>p. ct.</i> 73.4091 ± .1935	<i>p. ct.</i> 53.7182 ± .1823	1.3637 ± .0701
1909. . . . .	78	16.5308 ± .0625	9.7051 ± .0342	58.6410 ± .1521	8.8487 ± .0337	6.6718 ± .0286	75.2179 ± .2163	53.3974 ± .1315	1.5595 ± .0712
Dex., all years. . .	147	16.6235 ± .0462	9.6986 ± .0242	58.2143 ± .1266	8.9109 ± .0242	6.6442 ± .0205	74.3299 ± .1558	53.4864 ± .1034	1.5164 ± .0507
Sin. . . . .	7	17.1928 ± .2694	10.1571 ± .1435	59.8333 ± .3397	9.1285 ± .1138	7.0143 ± .1050	77.0714 ± .2303	52.9286 ± .2676	1.7143 ± .1784
STANDARD DEVIATION.									
Dex., 1908. . . . .	55	0.8067 ± .0519	0.4051 ± .0260	2.4703 ± .1588	0.4141 ± .0266	0.3487 ± .0153	2.1275 ± .1368	2.0051 ± .1289	0.7715 ± .0495
1909. . . . .	78	.8185 ± .0442	.4483 ± .0242	1.9918 ± .1075	.4414 ± .0238	.3744 ± .0202	2.8325 ± .1529	1.7216 ± .0930	.9679 ± .0503
Dex., all years. . .	147	.8299 ± .0327	.4342 ± .0171	2.2755 ± .0895	.4357 ± .0171	.3687 ± .0145	2.8003 ± .1102	1.8589 ± .0731	.9296 ± .0358
Sin. . . . .	7	1.0568 ± .1905	.5628 ± .1015	1.3325 ± .2402	.4462 ± .0805	.4119 ± .0742	.9035 ± .1628	1.0498 ± .1892	.6999 ± .1261

<sup>1</sup>The numbers are respectively 55, 84, 153; 7.

All of the shells secured were unbanded, and dark brown, lighter rufous brown, or yellowish brown in color (plate 29, figs. 1 to 3). The sinistral shells (plate 29, figs. 4 and 5) in some cases possess a tinted margin of the aperture, but the tinge never approaches the pink color of the red *rubescens* specimens.

Passing now to the statistical analysis (table 128) we may unite all of the shells into one series for comparison with those of other valleys, and we may also compare the fuller series from the middle and upper parts of the inhabited area. In the latter case it is found that the former are longer and slenderer than the upland collection; the same may be said of their apertures. Hence the variety is not uniform throughout its area. Perhaps the larger size of the outward snails is due to a more searching elimination of the smaller and weaker individuals, as suggested by the facts in the case of *rubescens*.

The fecundity of the snails (table 129) is high in all three series, which is surprising in view of the different times and seasons of collection.

TABLE 129.—*Partula otaheitana affinis*. Papenoo Valley.

FECUNDITY.									HEREDITY.			
	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.		Young, dextral.	Young, sinistral.	Total.
Dex., 1908.....	55	45	81.8	48	69	117	2.60	2.12	Adults: Dex.. Sin..	133 3	0 8	133 11
1909.....	81	71	87.6	129	63	192	2.70	2.37				
Dex., all years.....	138	117	84.7	178	133	311	2.65	2.25	Total..	136	8	144
Sin., 1908, 1909.....	7	7	100	13	11	24	3.43	3.43				

Heredity (table 129) of the dextral character is invariable in the case of 133 young produced by such parents, but the sinistral adults bore reversed young in only 3 out of 11 instances. The data make it certain that the two form-classes are not genetically distinct; it would seem that the majority of reversed individuals arise by mutation from directly coiled parents.

*Partula otaheitana affinis erythræa* subvar. nov.—Farapa Valley.

Although the mouth of Farapa Valley is little more than a mile beyond that of Papenoo, the colony of the former area differs remarkably and presents features of the association as a whole that are truly distinctive. All the shells exhibit the fundamental characters that set this variety apart from other primary divisions, and many specimens are exact counterparts of the kinds described heretofore, but the secondary features of the majority are virtually unique; specifically, the plain examples exhibit a considerable amount of red that overshades the yellowish ground-color, while reddish bands encircle the whorls in a well-marked subdivision of the striped class, so that the distinctive taxonomic term *erythræa* is given to the colony as a whole for use as a brief designation. Nearly 600 adults and 30 adolescents were taken, while the embryonic young dissected out of the former amount to 506, all of which afford an ample representative series of the unique association. They are dextral without a single exception.

The classification of the adult shells, on the basis of coloration, is as follows:

	No. of adults.	Per cent of adults.	No. of adolescents.
Plain:			
Whitish or very light.....	23	3.9	0
Light.....	252	42.6	13
Dark.....	176	29.8	13
Banded:			
Reddish bands.....	43	7.3	2
Brown bands.....	97	16.4	2
	591	100	30

The first group of the plain class (plate 29, figs. 6 to 8) is made up of shells that are more or less decorticated derivatives of the second group; there are no such specimens among the adolescents, which might not be significant in view of the small series of partly grown individuals, and there are none among the 506 embryonic young—a fact of undoubted meaning. The second group (plate 29, figs. 9 to 14) corresponds to the "light" series of previous valleys, but it also comprises the plain shells with the reddish overcast of a more or less intense hue; in many cases the red tinge extends out upon the lip, which then exhibits a pink color. Such a character is only sporadic heretofore, as in Ahonu. The dark group (plate 29, figs. 15 to 18) includes the most typical representatives of the variety as a whole, although strigations are not as well marked as in the more western colonies.

TABLE 130.—*Partula otaheitana affinis erythræa*. Farapa Valley.

MEAN VALUE.									
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index. <sup>1</sup>
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
Plain, white.... yellow.... brown....	23	mm. 18.2978 ± .0810	mm. 10.6130 ± .0614	p. ct. 57.7609 ± .3425	mm. 9.6913 ± .0465	mm. 7.4130 ± .0489	p. ct. 76.3261 ± .2707	p. ct. 52.7174 ± .2345	1.0870 ± .0385
	251	17.7834 ± .0402	10.2569 ± .0181	57.6395 ± .0912	9.3868 ± .0201	7.2123 ± .0134	76.7868 ± .1134	52.6832 ± .0603	1.1746 ± .0214
	173	17.7916 ± .0496	10.2757 ± .0213	57.7543 ± .1221	9.4202 ± .0244	7.2063 ± .0171	76.4191 ± .1434	52.8236 ± .0816	1.1648 ± .0230
Banded, reddish brown.	40	17.8325 ± .1080	10.2800 ± .0420	57.6000 ± .2799	9.4150 ± .0548	7.2050 ± .0363	76.4750 ± .2903	52.6000 ± .2418	1.0233 ± .0155
	95	17.8637 ± .0650	10.3568 ± .0298	58.0474 ± .1488	9.4200 ± .0354	7.2074 ± .0226	76.3316 ± .1708	52.7526 ± .1297	1.0928 ± .0241
Plain, all.....	447	17.8130 ± .0301	10.2825 ± .0137	57.6902 ± .0715	9.4177 ± .0149	7.2203 ± .0108	76.6208 ± .0845	52.7394 ± .0525	1.1663 ± .0151
Banded, all....	135	17.8544 ± .0580	10.3341 ± .0261	57.9149 ± .1341	9.4288 ± .0283	7.2066 ± .0192	76.3741 ± .1537	52.7074 ± .1161	1.0715 ± .0275
All.....	582	17.8227 ± .0265	10.2945 ± .0122	57.7423 ± .0632	9.4185 ± .0133	7.2172 ± .0094	76.5638 ± .0744	52.7320 ± .0485	1.1439 ± .0123
STANDARD DEVIATION.									
Plain, white.... yellow.... brown....	23	0.5763 ± .0572	0.4368 ± .0434	2.4355 ± .2421	0.3309 ± .0329	0.3481 ± .0345	1.9247 ± .1914	1.6669 ± .1658	0.2742 ± .0272
	251	.9455 ± .0284	.4264 ± .0128	2.1434 ± .0644	.4730 ± .0148	.3156 ± .0095	2.6640 ± .0795	1.4169 ± .0426	.5051 ± .0151
	173	.9668 ± .0360	.4166 ± .0115	2.3810 ± .0863	.4754 ± .0172	.3336 ± .0121	2.7964 ± .1013	1.5909 ± .0577	.4537 ± .0162
Banded, reddish brown.	40	1.0128 ± .0763	.4874 ± .0297	2.6248 ± .1979	.5136 ± .0387	.3405 ± .0256	2.7224 ± .2052	2.2671 ± .1709	.1510 ± .0109
	95	.9398 ± .0460	.4311 ± .0211	2.1509 ± .1052	.5112 ± .0250	.3267 ± .0160	2.4690 ± .1206	1.8749 ± .0912	.3514 ± .0170
Plain, all.....	447	.9454 ± .0213	.4302 ± .0097	2.2420 ± .0505	.4690 ± .0105	.3376 ± .0074	2.6485 ± .0597	1.6449 ± .0371	.4768 ± .0107
Banded, all....	135	.9622 ± .0410	.4498 ± .0184	2.3106 ± .0948	.4876 ± .0200	.3310 ± .0136	2.5485 ± .1087	2.0007 ± .0821	.3085 ± .0194
All.....	582	.9494 ± .0187	.4353 ± .0086	2.2609 ± .0447	.4765 ± .0094	.3360 ± .0066	2.6602 ± .0526	1.7338 ± .0343	.4448 ± .0087

<sup>1</sup>The numbers are respectively 23, 252, 176; 43, 97; 451, 140; 591.

The banded shells are especially interesting and peculiar. The red-striped group comprises (a) examples with very faint bands, sometimes only the median one being evident (plate 29, figs. 19 and 20); (b) others with separate though indistinct sutural, median, and basal markings (plate 29, fig. 21); and (c) a most novel series in which part of the last whorl is suffused with red, while the rest of it, like the spire, exhibits three bands as in (b), (plate 29, figs. 22 and 23). In the division distinguished by brown revolving bands, the same subordinate types occur (plate 29, figs. 24 to 29) all the more clearly because the stripes are usually sharp and distinct; the 3-banded type anticipates *dubia* of later valleys. The terminal suffusion of bands is not an uncommon feature in other colonies of *affinis*, but there it is a prominent character of the colony, as it is not elsewhere, although it occurs also in certain associations of *Partula otaheitana sinistralis* from the other side of the island.

When the several divisions are compared on the basis of their statistical characters (table 130) their substantial similarity is revealed. Certainly the plain and banded classes are alike in the morphology of the shell. Only the plain decorticated shells differ to an appreciable degree in absolute measures, but not in the proportionate figures; it is interesting to find a larger size associated with the physiological quality that results in the decortication of the surface during the later growth of the shell.

TABLE 131.—*Partula otaheitana affinis erythræa*. Farapa Valley. Fecundity.

Series.	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.
Plain, white . . . . .	23	22	95.6	39	22	61	2.77	2.65
yellow . . . . .	252	241	95.6	512	231	743	3.08	2.94
brown . . . . .	176	166	94.3	368	157	525	3.16	2.98
Banded, light . . . . .	40	38	95.0	88	39	127	3.34	3.02
brown . . . . .	69	66	95.6	142	57	199	3.01	2.88
Plain, all . . . . .	451	429	95.1	919	410	1,329	3.10	2.95
Banded, all . . . . .	109	104	95.4	230	96	326	3.13	2.99
All . . . . .	560	533	95.2	1,149	506	1,655	3.11	2.95

The fecundity of all groups (table 131) is well above the average. As the eggs greatly outnumber the advanced embryonic young, it would seem that reproductive activity had only recently been resumed at the time the snails were collected.

Passing to the statistics of heredity (table 132), the first point to be noted is that the "whitish" adults bear yellowish or brown young, banded in only 1 out of 22 cases, but none that displays the distinctive parent character. Plain adults produce unbanded as well as banded young of both color-types, and the banded adults also produce practically all kinds of young. A slight excess of plain young snails appears in the summary, which may indicate a small secular change in the proportionate numbers of the two primary classes of the succeeding generations, or it may be due to the difficulty of detecting the faint bands in the embryonic series of snails with small shells. In any case the positive observations remain that the various color-divisions of the Farapa colony breed true to their respective types in the main, and that they also contribute young to the other groups.

TABLE 132.—*Partula otaheitana affinis erythræa*. Farapa Valley. Heredity.

	Young, plain.		Young, banded.		All plain.	All banded.	Total.
	Light.	Brown.	Reddish.	Brown.			
Adults:							
Plain:							
Whitish.....	13	8	1	..	389	21	{ 22 231 157 } 410
Light.....	155	71	5	..			
Brown.....	73	69	8	7			
Banded:							
Reddish.....	15	..	21	3	40	56	{ 39 21 36 } 96
Brown, distinct....	5	4	1	11			
suffused....	8	8	..	20			
Total.....	269	160	36	41	429	77	506

## THE EASTERN SERIES OF AFFINIS—FAARUMAI TO FAONE VALLEYS.

In the valleys of the eastern sector beyond Farapa, *affinis* exists in substantial numbers; the coil is dextral except in a few individuals from one valley only, and the unbanded form of coloration predominates to degrees that vary from 76 to 99 per cent. The red over-tinge, which is a colonial character of the single Farapa association, disappears almost entirely, being exhibited by infrequent individuals just as in Ahonu; the light red bands of so large a number of the *erythræa* shells never recur.

Two types of shells with brown encircling bands occur in varying numbers in the eastern valleys and elsewhere to the southeast, excepting only in Tehoro and Haavini Valleys. In the one form the three bands are narrow and are sutural, median, and basal or umbilical in position; this is the *dubia* color-form now encountered for the first time as a distinct type, though certain of the Farapa shells anticipated it. Its status in the literature is somewhat peculiar. Pilsbry states (p. 189) "the var. *dubia* was not defined by Pease, but only mentioned as a form of *varia*, in P. Z. S. 1864, p. 675. Its first published definition was in Garrett's note \* \* \*," quoted herein on page 186. In his own volume on *Partula*, Pilsbry regards the distinctive coloration as a character of a primary varietal value, thus making *dubia* equivalent to *rubescens*, *amabilis*, etc., as well as to *affinis* itself; as a matter of fact *dubia* is not independent of the last-named, but is merely a color-form of that primary division of *Partula otaheitana*, and is to be written *dubia*. The second color-form, called *zonata*, replaces the narrow bands by broad stripes; transitional forms between this and *dubia* are found in several valleys.

If these two types occurred only in separate territories, and if each constituted a very large or preponderating section of the population in its valleys, then we would be justified in giving the terms the taxonomic value of secondary varietal distinctions, speaking of *P. o. affinis dubia* and *P. o. affinis zonata*. As a matter of fact, the banded shells of either type never predominate, while furthermore their territories are not distinct, like those of *sinistrorsa*, *sinistralis*, and *crassa* of the southern regions of Tahiti. At times both color-forms exist in the same valley, while at others a colony comprising *dubia* is found to lie in the midst of series of valleys in which only *zonata* banded shells occur. It is possible that in the course of the future



differentiation of this whole primary variety, *dubia* in some valleys and *zonata* in others will become the sole or nearly exclusive kind; under such circumstances, the terms would justly be used to apply to secondary varieties, but at present we do not find that the resolution of *affinis* into different subdivisions, possessing distinctive minor characters and inhabiting separate localities, has proceeded far enough to warrant the specifications of secondary varieties by taxonomic terms, except in the case of the Farapa colony. The two color-forms appearing in the territory now under consideration are always genetically related to their plain associates, and the names applied to them are useful primarily for the accurate description of the present conditions of the snails belonging to the variety *affinis*.

## FAARUMAI VALLEY.

Among 334 adults, all but 13 are devoid of bands and fall into whitish, light, and dark groups (plate 29, figs. 30 to 33). The banded specimens exhibit 3 stripes (plate 29, figs. 34 to 36), now and then of an aberrant character (fig. 36), and answer to the description of *dubia*, although Garrett assigns that color-form to a valley about 8 miles from Papenoo, to be identified with *Mahaena* in all probability.

TABLE 133.—*Partula otaheitana affinis*. *Faarumai Valley*.

MEAN VALUE.									
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
		<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>p. ct.</i>	
Plain, white...	20	15.7550±.1044	9.2900±.0629	58.9500±.2359	8.1200±.0602	6.4000±.0472	78.7000±.4228	51.5500±.2633	.....
yellow...	72	15.5459±.0504	9.2084±.0270	59.1944±.1604	8.1388±.0294	6.4028±.0229	78.5833±.1825	52.2640±.1543	.....
brown...	208	15.5145±.0301	9.2798±.0168	59.7404±.0919	8.1855±.0172	6.4202±.0132	78.3413±.1089	52.6730±.0849	.....
Plain, all.....	300	15.5380±.0252	9.2634±.0140	59.5566±.0770	8.1700±.0145	6.4147±.0111	78.4233±.0920	52.5000±.0727	2.4267±.0346
Banded.....	13	15.5577±.0944	9.3461±.0690	60.5084±.2899	8.2692±.0686	6.4539±.0490	77.9615±.5168	52.9615±.3166	2.1539±.1615
All.....	313	15.5388±.0245	9.2668±.0132	59.5767±.0748	8.1741±.0142	6.4163±.0107	78.4041±.0907	52.5191±.0713	2.4154±.0341
STANDARD DEVIATION.									
Plain, white...	20	0.6924±.0738	0.4170±.0444	1.5644±.1668	0.3995±.0438	0.3130±.0333	2.8035±.2989	1.7457±.1862	.....
yellow...	72	.6348±.0356	.3398±.0146	2.0182±.1133	.3706±.0208	.2887±.0162	2.3086±.1290	1.9415±.1091	.....
brown...	208	.6444±.0213	.3586±.0114	1.9660±.0649	.3682±.0121	.2835±.0093	2.3285±.0770	1.8158±.0600	.....
Plain, all.....	300	.6481±.0178	.3598±.0099	1.9766±.0554	.3717±.0102	.2869±.0078	2.3617±.0650	1.8672±.0514	.8896±.0244
Banded.....	13	.5045±.0667	.3692±.0488	1.5500±.2050	.3667±.0487	.2620±.0346	2.7628±.3664	1.6923±.2239	.8635±.1142
All.....	313	.6427±.0173	.3467±.0093	1.9630±.0529	.3720±.0100	.2804±.0076	2.3814±.0641	1.8712±.0504	.8938±.0255

TABLE 134.—*Partula otaheitana affinis*. *Faarumai Valley*.

FECUNDITY.									HEREDITY.			
	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.		Young, plain.	Young, banded.	Total.
Plain.....	300	202	67.3	318	104	422	2.09	1.41	Adults: Plain..... Banded...	102	2	104
Banded...	13	6	46.1	9	3	12	2.00	0.92		2	1	3
Total.....	313	208	66.4	327	107	434	2.08	1.38	Total.....	104	3	107

The shells of this colony are individually and collectively of astonishingly small size, as shown by the illustrations and the statistics (table 133). It is noteworthy that the banded shells differ from the rest in very much the same ways as in the Farapa association.

Fecundity (table 134) is lower than heretofore; the eggs outnumber the advanced young, thus proving that reproductive activity had recently been resumed.

The numbers of plain and banded young agree exactly with those of the corresponding groups of gravid adults (table 134), not because the two types breed true, but because complementary contributions are made by each class to the other one.

#### TIAREI VALLEY.

The small collection from Tiarei is interesting on account of its general agreement with the Faarumai series. The banded shells are more numerous relatively, and resemble the Farapa types with suffusion on the body whorl. One specimen (plate 29, fig. 37) exhibits only a partial clouding near the suture. In size (table 135) the shells are collectively small, but their colonial averages slightly exceed those of the preceding valley.

TABLE 135.—*Partula otaheitana affinis*. Tiarei Valley.

MEAN VALUE.									
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
		<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>p. ct.</i>	
Plain.....	135	16.1923 ± .0418	9.2882 ± .0232	57.1445 ± .1189	8.3504 ± .0225	6.3563 ± .0185	76.0630 ± .1310	51.4186 ± .0961	2.4593 ± .0493
Banded...	16	16.4750 ± .1004	9.4125 ± .0519	57.1250 ± .2788	8.5125 ± .0526	6.4500 ± .0484	75.8125 ± .5647	51.6250 ± .2590	2.5625 ± .1177
All.....	151	16.2222 ± .0377	9.3013 ± .0200	57.1424 ± .1104	8.3675 ± .0211	6.3662 ± .0174	76.0364 ± .1316	51.4404 ± .0903	2.4702 ± .0459
STANDARD DEVIATION.									
Plain.....	135	0.7202 ± .0295	0.3974 ± .0164	2.0493 ± .0831	0.3878 ± .0159	0.3189 ± .0131	2.2562 ± .0989	1.6558 ± .0679	0.8499 ± .0348
Banded...	16	.5953 ± .0710	.3079 ± .0367	1.6536 ± .1971	.3120 ± .0371	.2872 ± .0342	3.3488 ± .3993	1.5360 ± .1831	.7043 ± .0812
All.....	151	.6865 ± .0267	.3649 ± .0141	2.0115 ± .0781	.3836 ± .0149	.3170 ± .0123	2.3969 ± .0931	1.6448 ± .0639	.8363 ± .0324

Fecundity (table 136) is average. The figures for heredity (table 136) show a slight excess of plain young.

TABLE 136.—*Partula otaheitana affinis*. Tiarei Valley.

FECUNDITY.									HEREDITY.			
Series.	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.		Young, plain.	Young, banded.	Total.
Plain.....	132	114	86.3	192	80	272	2.39	2.06	Adults: Plain..... Banded...	78	2	80
Banded...	16	12	75.0	15	13	28	2.33	1.75		6	7	13
Total.....	148	126	85.1	207	93	300	2.38	2.02	Total.....	84	9	93

## MAHAENA VALLEY.

This is the original home of the 3-banded shells (plate 29, figs. 38 and 39) called *dubia* (= *dubia*) by Pease, Garrett, and Pilsbry. In the introductory pages of the section, Garrett's specific remarks have been quoted, and the differences between the situation depicted by him and that of the present have been duly noted. In addition to the fact that Garrett found no striped *affinis* elsewhere, whereas in my own collections they appear in 19 other localities, it is noteworthy that Garrett took no sinistral *affinis* outside of Papenoo. In Mahaena both plain and banded reversed snails (plate 29, figs. 40 and 41) now exist in small numbers. Certainly, then, the complexion of this colony has changed greatly during recent years.

The statistics (table 137) show that the shells are slightly larger than those of Tiarei. The two color-classes are substantially the same, allowing for the high probable errors due to small numbers.

TABLE 137.—*Partula otaheitana affinis*. Mahaena Valley.

MEAN VALUE.									
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
Dex., plain . . . . .	132	<i>mm.</i> 16.6954 ± .0429	<i>mm.</i> 9.6940 ± .0210	<i>p. ct.</i> 58.0228 ± .1273	<i>mm.</i> 8.7484 ± .0234	<i>mm.</i> 6.8325 ± .0181	<i>p. ct.</i> 78.0075 ± .1387	<i>p. ct.</i> 52.3258 ± .1080	3.0151 ± .0468
banded . . . . .	5	16.7900 ± .1557	9.8200 ± .0615	59.1000 ± .5594	8.9400 ± .0451	6.8200 ± .2039	77.3000 ± .2257	53.1000 ± .4091	2.8000 ± .2257
Dex., all . . . . .	137	16.6989 ± .0414	9.6985 ± .0204	58.0620 ± .1249	8.7555 ± .0227	6.8314 ± .0176	77.9818 ± .1341	52.3540 ± .1055	3.0073 ± .0459
Sin., plain . . . . .	3	17.2500 ± .2400	10.9000 ± .2293	62.8333 ± .6617	9.6333 ± .2044	7.5666 ± .1324	78.8333 ± .3671	55.5000 ± .8412	2.0000 ± .0
banded . . . . .	1	16.85	10.10	60.50	8.90	7.10	78.50	52.50	4.0
Sin., all . . . . .	4	17.1500 ± .1893	10.7000 ± .2079	62.2500 ± .6021	9.4500 ± .1870	7.4500 ± .1204	78.7500 ± .2797	54.7500 ± .7681	2.5000 ± .2920
STANDARD DEVIATION.									
Dex., plain . . . . .	132	0.7304 ± .0303	0.3584 ± .0148	2.1686 ± .0900	0.3985 ± .0165	0.3080 ± .0128	2.3629 ± .0980	1.8402 ± .0763	0.7975 ± .0330
banded . . . . .	5	.5161 ± .1101	.2039 ± .0435	1.8547 ± .3955	.1496 ± .0319	.2039 ± .0435	.7483 ± .1596	1.3564 ± .2893	.7483 ± .1596
Dex., all . . . . .	137	.7187 ± .0293	.3547 ± .0144	2.1676 ± .0883	.3939 ± .0161	.3050 ± .0124	2.3275 ± .0948	1.8305 ± .0746	.7973 ± .0324
Sin., plain . . . . .	3	.6164 ± .1697	.5888 ± .1621	1.6994 ± .4679	.5249 ± .1445	.3400 ± .0936	.9428 ± .2596	2.1602 ± .5948	0
banded . . . . .	1	.....	.....	.....	.....	.....	.....	.....	0
Sin., all . . . . .	4	.5612 ± .1339	.6164 ± .1470	1.7853 ± .4257	.5545 ± .1322	.3570 ± .0851	.8293 ± .1978	2.2776 ± .5431	.8660 ± .2064

TABLE 138.—*Partula otaheitana affinis*. Mahaena Valley.

FECUNDITY.									HEREDITY.			
Series.	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.		Young, dex., plain.	Young, sin., plain.	Total.
Dex., plain . . . . .	130	122	93.8	171	114	285	2.33	2.19	Adults:			
banded . . . . .	5	5	100	4	7	11	2.20	2.20	Dex., plain . . . . .	114	..	121
Sin., plain . . . . .	3	2	66.6	4	2	6	3.00	2.00	banded . . . . .	7	..	
banded . . . . .	1	1	100	1	0	1	1.00	1.00	Sin., plain . . . . .	...	2	2
All . . . . .	139	130	93.5	180	123	303	2.32	2.18	Total . . . . .	121	2	123

In fecundity (table 138) there is nothing of note, but the data of heredity (table 138) are decidedly interesting. All of the young are unbanded, like the 15 adolescents secured in this valley; possibly, therefore, the stripes are developed only late in life, but perhaps it is more likely that the dubia type is disappearing. Garrett speaks of a small colony of this form, but unfortunately he does not give a definite statement as to the presence of unbanded associates. Future studies of the colony will be most useful for the determination of this point. Finally it is important that the two young of reversed parents were also sinistral and that all of the young borne by dextral parents were directly coiled. None the less, snails of the former kind must be regarded as genetic relatives of the latter, for there are no other reversed *affinis* nearer than Papenoo, 8 miles away.

## VAHII VALLEY.

In this region a flourishing colony of *affinis* was found, although not a single adult or immature specimen of *rubescens* was taken. All but three of the full-grown shells are plain, and fall into light, medium, and dark groups (plate 29, figs. 42 to 44), but their comparison is relatively unimportant. The three *banded* shells (plate 29, figs. 45 to 47) are not dubia, but representatives of the other color-type, *zonata*, now met for the first time as such. The narrow median band of dubia is much broadened toward the right, and slightly to the left, while the sutural band is widened toward the sagittal plane of the shell, leaving only a narrow strip of the ground-color between it and the median element. The basal marking does not broaden to the same degree.

TABLE 139.—*Partula otaheitana affinis*. Vahii Valley.

MEAN VALUE.									
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index. <sup>1</sup>
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
Plain . . . . .	404	mm. 16.6554 ± .0244	mm. 9.9316 ± .0128	p. cl. 59.4950 ± .0649	mm. 9.0113 ± .0141	mm. 6.9732 ± .0107	p. cl. 77.3341 ± .0786	p. cl. 53.9653 ± .0565	2.3700 ± .0422
Banded, A. . . . .	.....	18.05	9.30	51.5	8.90	6.70	75.5	45.8	3.0000 ± .3179
B. . . . .	.....	15.95	9.50	59.5	8.70	6.70	77.5	55.5	
C. . . . .	.....	15.65	9.70	61.5	8.50	6.50	77.5	53.5	
All . . . . .	407	16.6546 ± .0245	9.9285 ± .0128	59.4803 ± .0659	9.0091 ± .0140	6.9708 ± .0106	77.3256 ± .0780	53.9545 ± .0569	2.3793 ± .0420
STANDARD DEVIATION.									
Plain . . . . .	404	0.7291 ± .0172	0.3813 ± .0095	1.9358 ± .0459	0.4198 ± .0096	0.3181 ± .0075	2.3431 ± .0556	1.6854 ± .0399	0.8849 ± .0298
All . . . . .	407	.7322 ± .0173	.3818 ± .0091	1.9719 ± .0466	.4193 ± .0099	.3181 ± .0075	2.3336 ± .0552	1.7031 ± .0402	.8872 ± .0297

<sup>1</sup>The numbers are, respectively, 200, 3; 203.

The statistics (table 139) are valuable mainly for an inter-valley comparison; yet it is significant that the banded shells are quite different from one another and hence are presumably sporadic products of plain parents rather than representatives of a distinct but feeble stock. They have no exact counterparts in the valleys on either side of Vahii.

Fertility (table 140) is low in the whole series, yet the snails were collected only a day later than the Mahaena snails. All of the young are plain and dextral; possibly the bands develop only later.

TABLE 140.—*Partula otaheitana affinis*. Vahii Valley. Fecundity.

	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.
Plain.....	194	171	88.1	208	122	330	1.93	1.70
Banded.....	3	1	33.3	1	1	2	2.00	0.66
All.....	197	172	87.3	209	123	332	1.93	1.68

## PARAURA VALLEY.

The collection of *affinis* representing the thriving colony of the valley comprises 466 plain adults and 60 similar adolescents, together with 113 banded adults and 13 partly grown individuals displaying bands. The former fall into three subordinate groups of light, medium, and dark brown (plate 29, fig. 48) shells. Among the last is a giant of enormous relative size (plate 29, fig. 49), which was none the less an *adolescent* devoid of the lip; its great degree of growth is emphasized by its contrast with a diminutive adult bearing young whose shell is illustrated in figure 33.

The banded shells are mostly of the *zonata* type, although a few dubia occur also; they fall into two subdivisions, in one of which (plate 29, fig. 50) the bands are faint but recognizable, while in the other they are strongly developed (plate 29, fig. 51), without suffusion over the last whorl, like that observed in Farapa and a few other instances.

TABLE 141.—*Partula otaheitana affinis*. Paraura Valley.

MEAN VALUE.									
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
Plain, light . . . . yellow brown. brown. . .	11	<i>mm.</i> 16.6863 ± .0837	<i>mm.</i> 9.8818 ± .0560	<i>p. ct.</i> 58.1364 ± .4445	<i>mm.</i> 8.9000 ± .0694	<i>mm.</i> 6.7545 ± .0428	<i>p. ct.</i> 75.7728 ± .3255	<i>p. ct.</i> 53.2272 ± .2466	2.6909 ± .0940
	100	16.4450 ± .0554	9.6600 ± .0281	58.6800 ± .1370	8.6760 ± .0318	6.6760 ± .0244	76.9800 ± .1337	52.5800 ± .1186	2.0500 ± .0575
	349	16.2509 ± .0253	9.6628 ± .0133	59.3596 ± .0793	8.6416 ± .0147	6.6731 ± .0115	77.0902 ± .0845	53.0702 ± .0652	1.9412 ± .0343
Plain, all. . . . . Banded. . . . .	460	16.3035 ± .0229	9.6674 ± .0119	59.1826 ± .0688	8.6552 ± .0133	6.6757 ± .0102	77.0348 ± .0711	52.9674 ± .0565	1.9875 ± .0290
	113	16.3217 ± .0464	9.6186 ± .0229	58.8805 ± .1405	8.6576 ± .0251	6.6682 ± .0183	76.9151 ± .1623	52.8982 ± .1125	2.0442 ± .0532
All. . . . .	573	16.3071 ± .0206	9.6578 ± .0106	59.1230 ± .0619	8.6557 ± .0118	6.6742 ± .0090	77.0113 ± .0654	52.9538 ± .0505	2.0000 ± .0255
STANDARD DEVIATION.									
Plain, light . . . . yellow brown. brown. . .	11	0.4117 ± .0592	0.2757 ± .0396	2.1856 ± .3143	0.3411 ± .0491	0.2105 ± .0302	1.6006 ± .2302	1.2129 ± .1743	0.4621 ± .0664
	100	.8209 ± .0391	.4166 ± .0198	2.0316 ± .0969	.4718 ± .0225	.3625 ± .0172	1.9823 ± .0945	1.7584 ± .0838	.8529 ± .0406
	349	.7009 ± .0179	.3769 ± .0094	2.1979 ± .0561	.4088 ± .0104	.3180 ± .0081	2.3396 ± .0597	1.8054 ± .0461	.8645 ± .0242
Plain, all. . . . . Banded. . . . .	460	.7301 ± .0162	.3785 ± .0084	2.1867 ± .0496	.4237 ± .0094	.3264 ± .0072	2.2604 ± .0502	1.7960 ± .0399	.8616 ± .0205
	113	.7308 ± .0328	.3615 ± .0162	2.2154 ± .0993	.3959 ± .0177	.2885 ± .0129	2.5581 ± .1147	1.7732 ± .0795	.8382 ± .0376
All. . . . .	573	.7304 ± .0146	.3758 ± .0075	2.1958 ± .0438	.4185 ± .0083	.3193 ± .0064	2.3226 ± .0462	1.7911 ± .0357	.8561 ± .0180

Analyzed on the basis of the statistics (table 141), the lightest shells prove to be larger than the rest—a relation disclosed in previously described colonies. The banded shells are substantially the same as their plain relatives.

The fecundity of the series (table 142) is such as to provide a large number of young for the consideration of heredity (table 142). As before, there is a dearth of banded young; yet among the adolescents, which represent an intermediate generation, this color-form was represented by a large percentage. The discrepancies observed are difficult to interpret.

TABLE 142.—*Partula otaheitana affinis*. Paraura Valley.

FECUNDITY.									HEREDITY.			
Series.	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.		Young, plain.	Young, banded.	Total.
Plain.....	400	355	88.7	490	227	717	2.02	1.79	Adults:			
Banded...	112	95	84.8	137	51	188	1.98	1.68	Plain.....	225	2	227
									Banded...	46	5	51
All.....	512	450	87.8	627	278	905	2.01	1.76	Total.....	271	7	278

## FAATAUTIA, PAPEIHA, UTUUFAL, AND FAONE VALLEYS.

The combined discussion of the *affinis* colonies existing in these four valleys does not imply that no discernible or significant differences are displayed, but only that the associations are sufficiently uniform to render separate treatment unnecessary. By no means negligible is the lack of similarity in the absolute or relative abundance of this primary variety, for it signifies a real constitutional variation of the colonies, on a par with that displayed in the relative numbers of the two major color-classes or in the dimensions of the shells.

The figures given earlier show that the plain and banded classes are numerically in the proportions of 3 : 1, 10 : 1, 4 : 1, and 7 : 1, respectively. The banded shells are all dubia in Faatautia (plate 29, fig. 52), while both types occur in the other valleys (plate 29, fig. 53, example from Papeiha).

The statistics relating to the shells (table 143) show differences between colonies of contiguous areas, manifested sometimes in one character and at other times in another measure or relation; in general, a color-class agrees more with the other class of its own region than with the similar group of a neighboring area. The collective statistical descriptions are more valuable for a general summary treatment of *affinis*. Considerable variation in fecundity is observed (table 144), although the collections were secured in the same year within a period of three days. Naturally the figures for Faatautia are the least significant.

The inheritance of the distinctive color-characters (table 145) seems to be quite consistent, if we disregard the small series from Faatautia. Each major class produces its own kind, but some of its offspring belong to the other group. The relative numbers in the adult and embryonic populations are closely similar in each of the three valleys yielding reliable data. It will be recalled that in certain earlier-described colonies (*e. g.*, that of Paraura) wide discrepancies were found; the substantial agreement in these cases tends to eliminate the supposition that a constant error of observation has been made.

TABLE 143.—*Partula otaheitana affinis. Faatautia, Papeiha, Utuufai and Faone Valleys.*

MEAN VALUE.									
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index. <sup>1</sup>
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
Faatautia, plain... banded...	9	mm 16.1500 ± .1311	mm. 9.3667 ± .0423	p. ct. 57.9445 ± .4753	mm. 8.2556 ± .0509	mm. 6.6334 ± .0423	p. ct. 80.2777 ± .3797	p. ct. 50.8334 ± .2370	3.3333 ± .1836
	3	16.2500 ± .2523	9.3667 ± .0366	57.8334 ± .7341	8.1667 ± .1318	6.6334 ± .0486	76.8333 ± .9713	50.5000 ± .5507	3.6666 ± .3671
Faatautia, all.....	12	16.1750 ± .1170	9.3667 ± .0331	57.9167 ± .4011	8.2333 ± .0507	6.6334 ± .0331	79.4166 ± .4733	50.7500 ± .1799	3.4166 ± .1655
Papeiha, plain... banded...	148	16.8297 ± .0380	9.7716 ± .0204	58.0068 ± .1184	8.9972 ± .0230	6.7378 ± .0173	74.8094 ± .1393	53.3108 ± .1011	2.7047 ± .0556
	14	17.0214 ± .0356	9.9142 ± .0601	58.2143 ± .3079	9.1275 ± .0795	6.7142 ± .0553	73.3572 ± .4355	53.7142 ± .3061	2.6858 ± .1693
Papeiha, all.....	162	16.8463 ± .0356	9.7852 ± .0195	58.0247 ± .1114	9.0086 ± .0222	6.7358 ± .0165	74.6667 ± .1344	53.3457 ± .0963	2.6107 ± .0527
Utuufai, plain... banded...	268	16.7145 ± .0322	9.7925 ± .0162	58.4777 ± .1249	8.8044 ± .0176	6.7268 ± .0159	76.3172 ± .0959	52.5074 ± .0668	3.2480 ± .0376
	70	16.4729 ± .0502	9.8142 ± .0276	59.5000 ± .1740	8.7400 ± .0284	6.6886 ± .0240	76.4715 ± .2210	53.0142 ± .1269	3.4142 ± .0765
Utuufai, all.....	338	16.6645 ± .0278	9.7970 ± .0141	58.6893 ± .0778	8.7911 ± .0151	6.7189 ± .0120	76.3491 ± .0888	52.6124 ± .0596	3.2843 ± .0339
Faone, plain... banded...	516	16.4942 ± .0222	9.7097 ± .0113	58.7868 ± .0622	8.6834 ± .0119	6.6744 ± .0091	76.8139 ± .0696	52.5426 ± .0307	3.1175 ± .0307
	71	16.4529 ± .0568	9.6324 ± .0377	58.3451 ± .1603	8.6493 ± .0345	6.6324 ± .0281	76.4859 ± .1659	52.4296 ± .1181	3.1805 ± .0787
Faone, all.....	587	16.4892 ± .0207	9.6997 ± .0110	58.7334 ± .0582	8.6792 ± .0113	6.6693 ± .0087	76.7743 ± .0645	52.5290 ± .0479	3.1271 ± .0286
STANDARD DEVIATION.									
Faatautia, plain... banded...	9	0.5831 ± .0927	0.1885 ± .0299	2.1140 ± .3361	0.2267 ± .0360	0.1885 ± .0299	1.6888 ± .2703	1.0541 ± .1678	0.8165 ± .1298
	3	.6481 ± .1784	.0942 ± .0259	1.8851 ± .5190	.3385 ± .0932	.1247 ± .0343	2.4944 ± .6868	1.4142 ± .3894	.9428 ± .2596
Faatautia, all.....	12	.6015 ± .0828	.1699 ± .0234	2.0598 ± .2836	.2605 ± .0359	.1699 ± .0234	2.4310 ± .3347	.9242 ± .1272	.8503 ± .1170
Papeiha, plain... banded...	148	.6849 ± .0268	.3687 ± .0144	2.1356 ± .0836	.4156 ± .0162	.3122 ± .0122	2.5128 ± .0985	1.8245 ± .0715	1.0067 ± .0393
	14	.4772 ± .0608	.3335 ± .0425	1.7083 ± .2680	.4409 ± .0572	.3067 ± .0391	2.4160 ± .3079	1.6984 ± .2164	.9395 ± .1197
Papeiha, all.....	162	.6716 ± .0252	.3677 ± .0138	2.1029 ± .0788	.4194 ± .0157	.3118 ± .0117	2.5368 ± .0950	1.8175 ± .0681	1.0013 ± .0372
Utuufai, plain... banded...	268	.7814 ± .0227	.3941 ± .0114	2.0605 ± .0883	.4276 ± .0124	.3862 ± .0112	2.3277 ± .0678	1.6207 ± .0472	.8823 ± .0266
	70	.6225 ± .0355	.3424 ± .0195	2.1580 ± .1236	.3523 ± .0200	.2983 ± .0169	2.7417 ± .1562	1.5743 ± .0897	.9486 ± .0541
Utuufai, all.....	338	.7576 ± .0197	.3841 ± .0100	2.1219 ± .0550	.4127 ± .0107	.3276 ± .0085	2.4199 ± .0628	1.6242 ± .0421	.8999 ± .0239
Faone, plain... banded...	516	.7469 ± .0157	.3811 ± .0080	2.0953 ± .0440	.4030 ± .0084	.3084 ± .0064	2.3448 ± .0492	1.7504 ± .0367	.9103 ± .0217
	71	.7099 ± .0401	.4710 ± .0266	2.0045 ± .1133	.4308 ± .0243	.3519 ± .0199	2.0725 ± .1173	1.4758 ± .0835	.9906 ± .0556
Faone, all.....	587	.7426 ± .0146	.3939 ± .0078	2.0895 ± .0412	.4071 ± .0080	.3143 ± .0062	2.3160 ± .0456	1.7199 ± .0339	.9233 ± .0202

<sup>1</sup>The numbers for Papeiha are 149, 14; 163. For Utuufai, 250, 70; 320. For Faone, 400, 72; 472.TABLE 144.—*Partula otaheitana affinis. Faatautia, Papeiha, Utuufai and Faone Valleys. \*Fecundity.*

Series.	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.
Faatautia, all.....	12	8	66.6	12	6	18	2.25	1.50
Papeiha, all.....	156	133	85.2	165	91	256	1.92	1.64
Utuufai, all.....	261	210	80.4	275	141	416	1.98	1.59
Faone, all.....	472	369	78.2	401	233	634	1.72	1.34

TABLE 145.—*Partula otaheitana affinis. Faatautia, Papeiha, Utuufai and Faone Valleys. Heredity.*

	Faatautia Valley.			Papeiha Valley.			Utuufai Valley.			Faone Valley.		
	Young, plain.	Young, banded.	Total.	Young, plain.	Young, banded.	Total.	Young, plain.	Young, banded.	Total.	Young, plain.	Young, banded.	Total.
Adults:												
Plain.....	2	2	4	78	3	81	104	11	115	187	8	195
Banded.....	..	2	2	6	4	10	6	20	26	21	17	38
Total.....	2	4	6	84	7	91	110	31	141	208	25	233



## THE NORTHERN TAIARAPU COLONIES—TEHORO AND HAAVINI VALLEYS.

## TEHORO VALLEY.

Instead of rounding the southeastern point of the island, we may pass from Faone to the northern side of Taiarapu, where in Tehoro and Haavini a novel type of coloration is met with, and where the *dubia* and *zonata* forms are lacking. Among the shells of the former colony (plate 29, figs. 54 to 59) 18.3 per cent are bicolored (figs. 57 to 59); that is, the right half of the body-whorl which adjoins the spire is lighter brown and the left half is darker in color although the difference between the two sides is not always very evident. The suture between successive whorls coincides very nearly with the median plane on which the color divides, but there is a slight darkening above the suture of the penultimate whorl that indicates a continuity of the bicolored pattern part way into the spire. Two of the 15 adolescent shells show this double coloration, but it does not appear in any of the embryonic individuals; hence we must conclude that it is developed only during later growth, if at all. The peculiar type is distinguished as the color-form *anomala*.

A few of the plain shells from Tehoro exhibit a red or pink color (plate 29, figs. 55 and 56) that recalls the notable feature of the Farapa colony. Such individuals are light-yellow otherwise, and belong to the first of the three distinguishable classes, viz, light, medium, and dark. In statistical respects (table 146) these three groups and the *anomala* class agree closely and they are collectively smaller than the shells of the nearest valleys in the eastern sector.

The statistics of fecundity are high (table 147) and remarkably uniform throughout the colony. Combining the plain and parti-colored parents and classifying them according to the intensity of the ground-color, the figures relating to the inheritance of the depth of color (table 147) give an excess of medium young and a deficiency in the dark class. Presumably the deep-brown coloration is attained only later in life by some individuals that have medium-brown shells as embryos.

TABLE 146.—*Partula otaheitana affinis*. Tehoro Valley.

MEAN VALUE.									
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index. <sup>1</sup>
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
		<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>p. ct.</i>	
Plain, yellow. . . . .	100	15.9740±.0484	9.4380±.0217	59.0300±.1512	8.4780±.0241	6.4540±.0193	75.9000±.1520	52.9800±.1295	.....
yellow brown. . . . .	55	16.0591±.0639	9.4746±.0271	58.8636±.2069	8.5255±.0292	6.4782±.0244	75.9909±.1750	53.0091±.1673	.....
brown. . . . .	92	16.0381±.0463	9.4044±.0253	58.5761±.1364	8.4500±.0280	6.4565±.0211	76.3696±.1653	52.5652±.1286	.....
Plain, all. . . . .	247	16.0168±.0298	9.4336±.0142	58.8238±.0923	8.4782±.0157	6.4604±.0124	76.0952±.0958	52.8319±.0808	3.3253±.0307
Half-banded. . . . .	56	16.0786±.0627	9.3608±.0274	58.1608±.1780	8.4893±.0256	6.4608±.0242	76.0000±.2462	52.7678±.1440	3.2142±.0531
All. . . . .	303	16.0282±.0259	9.4201±.0128	58.7013±.0828	8.4802±.0137	6.4604±.0096	76.0776±.0904	52.8201±.0713	3.3049±.0330
STANDARD DEVIATION.									
Plain, yellow. . . . .	100	0.7183±.0342	0.3221±.0153	2.2425±.1069	0.3576±.0170	0.2868±.0136	2.2538±.1075	1.9208±.0915	.....
yellow brown. . . . .	55	.7024±.0452	.2980±.0191	2.2753±.1463	.3215±.0206	.2688±.0172	1.9247±.1236	1.8377±.1183	.....
brown. . . . .	92	.6584±.0346	.3606±.0179	1.9406±.0964	.3985±.0198	.3004±.0149	2.3508±.1169	1.8285±.0909	.....
Plain, all. . . . .	247	.6942±.0211	.3330±.0100	2.1522±.0652	.3671±.0111	.2884±.0088	2.2329±.0677	1.8798±.0571	0.7188±.0217
Half-banded. . . . .	56	.6963±.0443	.3046±.0194	1.9755±.1257	.2839±.0181	.2684±.0171	2.7321±.1741	1.5983±.1018	.5890±.0375
All. . . . .	303	.6680±.0183	.3291±.0091	2.1362±.0585	.3533±.0097	.2471±.0068	2.3335±.0639	1.8401±.0504	.6981±.0233

<sup>1</sup>The numbers are, respectively, 249, 56; 305.



TABLE 147.—*Partula otaheitana affinis*. Tehoro Valley.

FECUNDITY.									HEREDITY.				
Series.	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.		Young, light.	Young, medium.	Young, dark.	Total.
Plain, light.....	100	88	88.0	136	66	202	2.29	2.02	Adults:				
medium.....	57	50	87.7	84	34	118	2.36	2.07	Light.....	28	29	12	69
dark.....	92	88	95.6	153	75	228	2.59	2.47	Medium....	15	18	4	37
									Dark.....	24	48	34	106
Plain, all.....	249	226	90.7	373	175	548	2.42	2.20	Total.....	67	95	50	212
Half-banded....	56	51	91.0	86	37	123	2.41	2.19					
All.....	305	277	90.8	459	212	671	2.42	2.20					

## HAAVINI VALLEY.

It is in this region that *rubescens* preponderates in the *otaheitana* population, while in Tehoro the relation is reversed. Here only 59 adults and 4 adolescents were taken, three of the former and one of the latter being sinistral; one of the examples illustrated exhibits a ruddy brown color (plate 29, fig. 60), but the rest of the reversed and dextral adults are typically yellow-brown or deep brown (plate 29, fig. 61). Five shells exhibited the bicolored anomala pattern, with a very slight difference between the two sides of the median plane.

TABLE 148.—*Partula otaheitana affinis*. Haavini Valley.

MEAN VALUE.									
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
Dex., plain.....	51	mm.	mm.	p. ct.	mm.	mm.	p. ct.	p. ct.	
	5	15.6500±.0705	9.3314±.0357	59.5000±.1988	8.4255±.0420	6.3667±.0296	74.5392±.1683	53.5980±.1727	1.9216±.0744
half-banded.	5	16.0100±.1557	9.2200±.0980	57.9000±.7289	8.4200±.1119	6.1800±.0980	72.7000±.8183	52.9000±.8658	1.4000±.1478
Dex., all.....	56	15.6821±.0664	9.3215±.0338	59.3571±.1968	8.4250±.0395	6.3500±.0288	74.3750±.1763	53.5357±.1762	1.8750±.0703
Sin., plain.....	3	15.0500±.1562	9.5667±.2407	63.1667±1.3237	8.1667±.1943	6.3000±.1682	75.8333±.4857	55.1667±1.0704	1.6667±.1835
STANDARD DEVIATION.									
Dex., plain.....	51	0.7467±.0498	0.3777±.0252	2.1051±.1406	0.4445±.0297	0.3135±.0209	1.7818±.1190	1.8285±.1221	0.7882±.0526
	5	.5161±.1101	.3250±.0693	2.4166±.5154	.3710±.0791	.3250±.0693	2.7129±.5786	2.8705±.6122	.4899±.1045
Dex., all.....	56	.7363±.0470	.3755±.0239	2.1829±.1392	.4384±.0279	.3190±.0204	1.9555±.1247	1.9545±.1246	.7806±.0497
Sin., plain.....	3	.4242±.1168	.6182±.1702	3.3993±.9360	.4989±.1374	.4320±.1189	1.2472±.3434	2.7487±.7569	.4714±.1297

Comparing the dextral and reversed shells (table 148) the latter prove to be shorter and stouter, and their apertures are shorter, slightly narrower, but relatively broader. It is true that no final conclusion can be based on the figures for only three shells, yet the data are significant so far as they are positive.

Passing by the matter of fecundity (table 149) with a mere reference, and taking up the data of heredity, it is found that all of the young are devoid of the bicolored pattern and that they are all dextral, even the four produced by the reversed adults. Hence the relationship between the sinistral group and the domi-

nant series is proven in this case by the return of the former's recorded young to what must be regarded as the ancestral form of coil; indirectly it would appear that the three adult and single adolescent of the minority type were the products of sporadic mutation on the part of dextral parents.

TABLE 149.—*Partula otaheitana affinis*. Haavini Valley. Fecundity.

Series.	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.
Dextral. ....	54	53	98.1	84	38	122	2.30	2.26
Sinistral. ....	3	2	66.6	1	3	4	2.00	1.33

## THE GENERAL TAIARAPU SERIES—TAUTIRA TO HAOMA VALLEYS.

In the remaining ten valleys of the peninsula where collections were made, *affinis* was found in varying absolute and relative numbers, excepting in Aiavaro; *rubescens* is an associate in the valleys as far as Aiurua, while *sinistrorsa* occupies the valleys of the southern tier from Vaiaaia to Vaipoe; hence in Vaiau, Hototunu, and Haoma *affinis* is the only variety of *P. otaheitana* so far as the collections indicate the facts. Plain sinistral examples appear in Vaiau and Vaiaaia. In six valleys banded individuals occur that are of the *zonata* pattern almost without exception.

The above general statements deserve considerable emphasis; it is by no means unimportant for the solution of our major problems that in Taiarapu there are three regions, the first (Tehoro to Aiurua) inhabited by *affinis* and *rubescens*, the second (Vaiau to Hototunu) inhabited by *affinis* alone, and the third (Vaiaaia to Haoma) inhabited by *affinis* and *sinistrorsa*. If the "environment" were primarily responsible for the production of *rubescens* in the northern valleys of Taiarapu, and of *sinistrorsa* in the southern tier of the peninsula, it would certainly be anomalous for *affinis* to exist, as it does, in all parts of that minor portion of Tahiti.

## TAUTIRA VALLEY.

In this large area (which is the ancient crater valley of Taiarapu, like Papenoo in Tahiti nui) *affinis* is well represented, 207 adults having been taken. All but 2 are plain with various shades of brown in color, except one shell with a red tone like the Tehoro specimen of plate 29, figure 56; this simulates the red type of sinistral *rubescens* found here and elsewhere. Two extreme variants in respect to shape and size are illustrated (plate 29, figs. 62 and 63). One of the two banded shells is so decorticated as to have lost the details of its pattern; the other (plate 29, fig. 64) has the wide basal band of *zonata*, but the median stripe is faint, except along its lower (left) border, so that it seems to be like *dubia* in the middle of the whorl.

The statistical data (table 150) bring out the essential agreement of the light, medium, and dark divisions of the plain class, allowing for the high probable errors involved. Owing to the exigencies of travel at the time, and a night's camp on an islet of the coral-reef, no fresh water was procurable for the expansion of the snails; consequently there are no data on fecundity and heredity.

TABLE 150.—*Partula otaheitana affinis*. Tautira Valley.

MEAN VALUE.									
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index. <sup>1</sup>
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
		<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>p. ct.</i>	
Plain, light . . . . .	8	15.8375 ± .1885	9.1750 ± .0672	57.7500 ± .4732	8.3250 ± .0874	6.2500 ± .0571	74.5000 ± .5332	52.3750 ± .2511	.....
yellow brown	27	15.7177 ± .0843	9.4260 ± .0550	60.2407 ± .2796	8.2630 ± .0400	6.3149 ± .0457	76.2778 ± .3504	53.6111 ± .2129	.....
brown . . . . .	168	16.0286 ± .0422	9.2988 ± .0211	58.0655 ± .1126	8.3869 ± .0216	6.2738 ± .0161	74.7560 ± .1079	52.1786 ± .0879	.....
Plain all . . . . .	203	15.9796 ± .0375	9.3109 ± .0192	58.3424 ± .1076	8.3680 ± .0192	6.2784 ± .0148	74.9483 ± .1038	52.2439 ± .0781	1.1951 ± .0240
Banded . . . . .	2	16.8500 ± .1430	9.2000 ± .0477	54.0000 ± .9539	8.0000 ± .2385	6.0000 ± .1430	73.5000 ± .4769	47.5000 ± 1.9076	1.0000 ± .0
All . . . . .	205	15.9880 ± .0374	9.3098 ± .0190	58.3049 ± .1088	8.3644 ± .0191	6.2756 ± .0148	74.9342 ± .1031	52.1976 ± .0817	1.1933 ± .0262
STANDARD DEVIATION.									
Plain light . . . . .	8	0.7904 ± .1333	0.2817 ± .0475	1.9843 ± .3346	0.3665 ± .0618	0.2397 ± .0404	2.2360 ± .3770	1.0532 ± .1775	.....
yellow brown	27	.6499 ± .0596	.4239 ± .0389	2.1533 ± .1977	.3081 ± .0283	.3525 ± .0323	2.6999 ± .2477	1.6405 ± .1505	.....
brown . . . . .	168	.8119 ± .0298	.4050 ± .0149	2.1647 ± .0796	.4155 ± .0152	.3090 ± .0114	2.0731 ± .0763	1.6450 ± .0621	.....
Plain, all . . . . .	203	.7918 ± .0265	.4055 ± .0136	2.2820 ± .0761	.4033 ± .0136	.3132 ± .0104	2.1931 ± .0734	1.6511 ± .0552	0.5141 ± .0169
Banded . . . . .	2	.3000 ± .1011	.1000 ± .0337	2.0000 ± .6745	.5000 ± .1686	.3000 ± .1011	1.0000 ± .3372	4.0000 ± 1.3972	.0
All . . . . .	205	.7930 ± .0264	.4038 ± .0134	2.3103 ± .0769	.4060 ± .0135	.3141 ± .0105	2.1891 ± .0729	1.7352 ± .0578	.5121 ± .0185

<sup>1</sup>The numbers are, respectively, 205, 2; 207.

## AIONIFAA, AIURUA, AND VAI AU VALLEYS.

The constitution of these three colonies has already been described. While no banded individuals were collected, 5 out of 16 taken in Vaiau were sinistral, and 2 of these were ruddy-brown in color with pink-tinged apertures (plate 30, figs. 1 and 2). All others were dark-brown, excepting 1 straw-yellow shell from Aionifaa.

The statistics (table 151) sufficiently describe the shells. It is significant that the sinistral individuals of Vaiau are shorter and stouter than their dextral relatives, precisely as in Haavini Valley.

TABLE 151.—*Partula otaheitana affinis*. Aionifaa, Aiurua, and Vaiau Valleys.

MEAN VALUE.									
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
		<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>p. ct.</i>	
Aionifaa, dex. . .	14	16.0143 ± .0984	9.2149 ± .0575	57.2858 ± .2064	8.3286 ± .0744	6.2000 ± .0447	74.2183 ± .3436	51.7857 ± .2925	1.0714 ± .0464
Aiurua, dex. . .	100	15.5810 ± .0436	9.1100 ± .0217	58.3500 ± .1472	8.1820 ± .0227	5.9780 ± .0161	72.9500 ± .1448	52.3600 ± .1129	1.0400 ± .0016
Vaiau, dex. . . .	11	15.5408 ± .1383	9.0273 ± .0834	58.0455 ± .3613	7.9909 ± .0903	6.1909 ± .0437	77.3181 ± .5333	51.4091 ± .2796	3.0909 ± .2203
sin. . . .	5	15.2900 ± .0887	9.5000 ± .0661	62.3000 ± .5849	8.2200 ± .0914	6.5400 ± .0800	79.5000 ± .4266	53.7000 ± .6986	2.2000 ± .2955
STANDARD DEVIATION.									
Aionifaa, dex. .	14	0.5460 ± .0696	0.3191 ± .0407	1.1452 ± .1460	0.4130 ± .0526	0.2478 ± .0316	1.9059 ± .2430	1.6225 ± .2068	0.2575 ± .0328
Aiurua, dex. . .	100	.6460 ± .0308	.3217 ± .0153	2.1830 ± .1041	.3371 ± .0161	.2394 ± .0114	2.1465 ± .1024	1.6734 ± .0798	.0242 ± .0013
Vaiau, dex. . . .	11	.6800 ± .0978	.4103 ± .0590	1.7768 ± .2555	.4438 ± .0639	.2151 ± .0309	2.6222 ± .3771	1.3750 ± .1977	1.0833 ± .1558
sin. . . .	5	.2939 ± .0627	.2191 ± .0467	1.9390 ± .4136	.3029 ± .0646	.2651 ± .0566	1.4142 ± .3002	2.3152 ± .4940	.9798 ± .2089

Four *Aionifaa* snails were gravid, and contained 5 eggs and 4 plain, brown, and dextral young. No figures were procured in the case of the *Aiurua* series. The *Vaiau* records are almost complete (table 152). As regards the inheritance of the mode of coil, it is evident that the two classes are not genetically separate, for one of the reversed parents produced a single dextral offspring.

TABLE 152.—*Partula otaheitana affinis*. *Vaiau Valley*.

FECUNDITY.									HEREDITY.			
Series.	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.		Young. dextral.	Young. sinistral.	Total.
Dextral...	9	4	44.4	3	3	6	1.50	0.66	Adults:			
Sinistral..	5	3	60.0	3	3	6	2.00	1.20	Dextral...	3	..	3
									Sinistral..	1	2	3
									Total.....	4	2	6

## HOTOTUNU TO HAOMA VALLEYS.

Although the *affinis* collections from the remainder of Taiarapu are small, they are of much interest on account of their differing colonial aspects. In Hototunu, 6 zonately banded shells occurred in a collection of 45 adults. In the next valley no such specimen was found in a short series of 6, but 1 plain sinistral individual was secured. Passing Aiavaro, where only *sinistrorsa* representatives of *P. otaheitana* were found, 1 out of 6 *affinis* from Vavii Valley is zonately banded. In Vaipoe the plain and the striped shells exist in the proportion of 4 to 3, respectively; while finally in Haoma the banded specimens dwindle again; some of the Vaipoe shells are so peculiar as to be worthy of illustration (plate 30, figs. 3 to 7).

The statistics relating to the various colonies and to their subordinate classes (table 153) require no verbal amplification. So far as the figures are reliable, they indicate that each colony possesses dimensional characteristics of its own.

Fecundity appears to be average (table 154) for the colonies which afford reliable data. The snails collected in Vaipoe were kept alive for several weeks, and hence there are no figures for that association.

The data of heredity are unfortunately scanty, but they are valuable. In Hototunu 22 young of plain parents were all plain; out of 6 young produced by banded snails, 4 were plain and 2 only were banded. The *Vaiaaia* data are remarkable, as the table (154) shows; specifically a dextral plain adult bore a young one like itself, a dextral banded snail produced one of similar coil and pattern, while a sinistral plain animal contained a sinistral and *banded* embryonic snail—a type that did not appear in the small series of adults! The Vavii and Vaipoe colonies furnished no data. In the case of the Haoma series, all 28 young of plain parents were plain, and 2 young from banded adults were also plain. Here, then, we have a repetition of the situation observed in the colonies of the northern Taiapapu series.

TABLE 153.—*Partula otaheitana affinis*. Hototunu, Vaiaaia, Vavii, Vaipoe, and Haoma Valleys.

MEAN VALUE.									
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index. <sup>1</sup>
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
Hototunu, plain, dex. . . . . banded, dex. . . . .	39	<i>mm.</i> 16.4423 ± .0841	<i>mm.</i> 9.6385 ± .0497	<i>p. ct.</i> 58.5769 ± .2273	<i>mm.</i> 8.6128 ± .0508	<i>mm.</i> 6.3821 ± .0341	<i>p. ct.</i> 74.0642 ± .2688	<i>p. ct.</i> 52.2436 ± .1874	1.0250 ± .0166
	6	16.5000 ± .1110	9.6334 ± .0410	58.5000 ± .1589	8.5767 ± .0519	6.2667 ± .0379	72.8334 ± .4680	52.0000 ± .3465	1.0000 ± .0
Hototunu, dex., all. . . . .	45	16.4500 ± .0744	9.6378 ± .0434	58.5666 ± .1982	8.6067 ± .0446	6.3667 ± .0303	73.9000 ± .2448	52.2111 ± .1691	1.0217 ± .0144
Vaiaaia, plain, dex. . . . . banded, dex. . . . .	4	16.0300 ± .2528	9.5500 ± .1930	59.2500 ± .7644	8.5500 ± .1744	6.4500 ± .1460	75.0000 ± .5592	53.0000 ± .1686	1.7500 ± .2796
	1	17.7500	10.3000	57.5000	9.3000	6.7000	72.5000	52.5000	1.0000 ± .0
Vaiaaia, all, dex. . . . . sin. . . . .	5	16.3700 ± .2896	9.7000 ± .1790	58.9000 ± .6497	8.7000 ± .1663	6.5000 ± .1207	74.5000 ± .5406	52.9000 ± .1478	1.6000 ± .2413
	1	16.8500	10.3000	61.5000	8.9000	6.7000	75.5000	53.5000	1.0000
Vavii, plain, dex. . . . . banded, dex. . . . .	5	16.0700 ± .3462	9.2200 ± .1052	57.7000 ± .6152	8.2600 ± .1106	6.1400 ± .1230	74.5000 ± .3815	51.5000 ± .4266	1.6000 ± .2413
	1	15.3500	9.1000	59.5000	7.9000	5.7000	72.5000	51.5000	1.0000
Vavii, all, dex. . . . .	6	15.9500 ± .2979	9.2000 ± .0885	58.0000 ± .5379	8.2000 ± .0993	6.0667 ± .1120	74.1667 ± .3785	51.5000 ± .3555	1.5000 ± .2103
Vaipoe, plain, dex. . . . . banded, dex. . . . .	40	16.6012 ± .0763	9.6100 ± .0407	57.7000 ± .2363	8.7650 ± .0427	6.3200 ± .0319	72.1750 ± .2659	52.6500 ± .1886	2.2875 ± .1049
	29	16.4673 ± .1103	9.4862 ± .0412	56.4655 ± .2951	8.8034 ± .0605	6.3690 ± .0442	72.1897 ± .3323	53.3276 ± .2713	2.0690 ± .1468
Vaipoe, all, dex. . . . .	69	16.5457 ± .0643	9.5580 ± .0351	57.6014 ± .1829	8.7811 ± .0355	6.3406 ± .0263	72.1812 ± .2080	52.9348 ± .1603	2.1884 ± .0866
Haoma, plain, dex. . . . . banded, dex. . . . .	41	16.9012 ± .0810	10.1390 ± .0430	59.9390 ± .2208	8.8609 ± .0521	6.9927 ± .0364	78.6707 ± .3322	52.4756 ± .1925	3.3658 ± .0727
	3	16.0500 ± .1101	9.9666 ± .1324	62.1666 ± .4857	8.5667 ± .1944	6.6334 ± .1600	77.5000 ± .6359	53.1666 ± .0917	2.6667 ± .1836
Haoma, all, dex. . . . .	44	16.8432 ± .0790	10.1273 ± .0413	60.0909 ± .2160	8.8409 ± .0510	6.9636 ± .0371	78.5909 ± .3140	52.5227 ± .1908	3.3181 ± .0711
STANDARD DEVIATION.									
Hototunu, plain, dex. . . . . banded, dex. . . . .	39	0.7790 ± .0594	0.4600 ± .0351	2.1047 ± .1607	0.4702 ± .0359	0.3161 ± .0241	2.4899 ± .1901	1.7352 ± .1318	0.1561 ± .0117
	6	.4031 ± .0785	.1491 ± .0290	.5773 ± .1123	.1886 ± .0367	.1375 ± .0268	1.6998 ± .3309	1.2583 ± .2450	.0
Hototunu, all, dex. . . . .	45	.7403 ± .0526	.4319 ± .0307	1.9709 ± .1401	.4434 ± .0315	.3011 ± .0214	2.4349 ± .1731	1.6815 ± .1196	.1453 ± .0102
Vaiaaia, plain, dex. . . . . banded, dex. . . . .	4	.7497 ± .1787	.5722 ± .1364	2.2666 ± .5404	.5172 ± .1233	.4330 ± .1032	1.6583 ± .3953	.5000 ± .1192	.8291 ± .1977
	1	.....	.....	.....	.....	.....	.....	.....	.....
Vaiaaia, all, dex. . . . . sin. . . . .	5	.9600 ± .2048	.5933 ± .1266	2.1540 ± .4594	.5514 ± .1176	.4000 ± .0853	1.7888 ± .3823	0.4899 ± .1045	.8000 ± .1706
	1	.....	.....	.....	.....	.....	.....	.....	.....
Vavii, plain, dex. . . . . banded, dex. . . . .	5	1.1478 ± .2448	.3487 ± .0744	2.0396 ± .4349	.3666 ± .0782	.4079 ± .0870	1.2649 ± .2697	1.4142 ± .3016	.8000 ± .1706
	1	.....	.....	.....	.....	.....	.....	.....	.....
Vavii, all, dex. . . . .	6	1.0817 ± .2106	.3214 ± .0626	1.9536 ± .3804	.3605 ± .0702	.4069 ± .0792	1.3744 ± .2676	1.2909 ± .2514	.7637 ± .1487
Vaipoe, plain, dex. . . . . banded, dex. . . . .	40	.7159 ± .0469	.3819 ± .0288	2.2158 ± .1671	.4009 ± .0302	.2993 ± .0225	2.4938 ± .1880	1.7684 ± .1333	.9835 ± .0742
	29	.8805 ± .0799	.3290 ± .0291	2.3559 ± .2086	.4831 ± .0428	.3534 ± .0312	2.6536 ± .2350	2.1666 ± .1918	1.1724 ± .1038
Vaipoe, all, dex. . . . .	69	.7921 ± .0455	.4322 ± .0248	2.2531 ± .1293	.4378 ± .0251	.3241 ± .0186	2.5622 ± .1471	1.9743 ± .1133	1.0669 ± .0612
Haoma, plain, dex. . . . . banded, dex. . . . .	41	.7695 ± .0572	.4078 ± .0304	2.0959 ± .1561	.4943 ± .0368	.3453 ± .0257	3.1538 ± .2349	1.8278 ± .1361	.6899 ± .0514
	3	.2828 ± .0778	.3399 ± .0936	1.2474 ± .3434	.5249 ± .1375	.4109 ± .1131	1.6329 ± .4496	2.3570 ± .0648	.4714 ± .1294
Haoma, all, dex. . . . .	44	.7768 ± .0559	.4058 ± .0292	2.1247 ± .1527	.5019 ± .0361	.3650 ± .0262	3.0882 ± .2220	1.8767 ± .1349	.6998 ± .0503

<sup>1</sup>The figures for Hototunu are: 40, 6; 46.

TABLE 154.—*Partula otaheitana affinis*. Southern Taiarapu Series.

FECUNDITY.									HEREDITY (VAIAAIA VALLEY).					
	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.		Young, dex., plain.	Young, dex., banded.	Young, sin., plain.	Young, sin., banded.	Total.
Hototunu, d. . . .	44	37	84.0	42	28	70	1.89	1.59	Adults:					
Vaiaaia, d. and s.	6	4	66.6	4	4	8	2.00	1.33	D., plain. . . .	1	..	..	..	1
Vavii, d. . . . .	6	2	33.3	2	0	2	1.00	0.33	D., banded. . .	..	1	..	..	1
Haoma, d. . . . .	44	40	90.9	59	30	89	2.22	2.02	S., plain. . . .	..	..	..	1	1
									Total. . . . .	1	1	..	1	3

## THE PAPEARI COLONIES—OOPU AND APIRIMAUE VALLEYS.

Having completed the circuit of Taiarapu, we return to Papeari, the south-eastern district of Tahiti nui, where *affinis* is found in two valleys of a region that articulates both with the peninsula and with the eastern series of valleys ending at Faone. In Oopu, 36 *affinis* were taken, of which 3 belonged to the zonata color-class (plate 30, fig. 8). Six plain shells only were collected in Apirimaue (plate 30, fig. 9), where *sinistrorsa* thrives in great abundance.

TABLE 155.—*Partula otaheitana affinis*. Oopu and Apirimaue Valleys.

MEAN VALUE.									
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
Oopu, plain. . . .	33	<i>mm.</i> 16.7318 ± .0827	<i>mm.</i> 9.8636 ± .0482	<i>p. ct.</i> 58.8030 ± .2211	<i>mm.</i> 8.8697 ± .0549	<i>mm.</i> 6.7363 ± .0344	<i>p. ct.</i> 75.9849 ± .2619	<i>p. ct.</i> 52.8333 ± .1826	2.3940 ± .1291
	3	17.0500 ± .1101	9.4334 ± .1324	59.8333 ± .3676	9.1000 ± .0640	6.7666 ± .0367	74.5000 ± .6359	53.1666 ± .3676	2.6667 ± .1836
Oopu, all. . . . .	36	16.7583 ± .0770	9.8278 ± .0474	58.8889 ± .2074	8.8889 ± .0510	6.7389 ± .0317	75.8445 ± .2496	52.8611 ± .1381	2.4167 ± .1197
Apirimaue. . . .	6	17.7500 ± .1262	10.1333 ± .1164	57.1667 ± .5877	9.0667 ± .0805	6.8000 ± .0693	74.5000 ± .4205	51.0000 ± .3711	1.6667 ± .1298
STANDARD DEVIATION.									
Oopu, plain. . . .	33	0.7043 ± .0585	0.4103 ± .0341	1.8827 ± .1563	0.4674 ± .0388	0.2932 ± .0243	2.2309 ± .1852	1.5555 ± .1298	1.0993 ± .0913
	3	.2828 ± .0778	.3399 ± .0936	.9428 ± .2599	.1633 ± .0452	.0942 ± .0259	1.6329 ± .4496	.9428 ± .2599	.4714 ± .1294
Oopu, all. . . . .	36	.6849 ± .0544	.4220 ± .0335	1.8451 ± .1467	.4533 ± .0361	.2821 ± .0224	2.2207 ± .1765	1.2282 ± .0976	1.0639 ± .0846
Apirimaue. . . .	6	.4582 ± .0892	.4229 ± .0823	2.1344 ± .4156	.2924 ± .0570	.2516 ± .0490	1.5271 ± .2973	1.3478 ± .2624	.4714 ± .0918

In dimensional respects the statistics (table 155) show that the Oopu shells resemble the Haoma series more than the Faone colony. The Apirimaue specimens are collectively larger than any others except the far-distant Farapa colony. In view of the fact that dextral examples of the large *sinistrorsa* type occur in Titaviri and other valleys immediately to the west, it might be supposed that some such shells were included in the so-called *affinis* series. But the differential characters of the specimens in question are those of *affinis*. Again, their variability is low, as it would not be if some of the so-called *affinis* shells were dextral sports from the larger *sinistrorsa* stock. Finally, all of their young were dextral, and all of the young of the associated series (169 in all) were sinistral like their own parents.

Taking all of these facts into account, it would seem that the dextral animals of Apirimaue are really *affinis*, despite their aberrant dimensional characteristics.

Fecundity (table 156) is not unusual. The data of inheritance of the color-characters in Oopu (table 156) show the interconnection of the two types. The 6 young of the Apirimaue adults were all brown, plain, and dextral like their parents.

TABLE 156.—*Partula otaheitana affinis*. Oopu and Apirimaue Valleys.

FECUNDITY.									HEREDITY (OOPU VALLEY).			
	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.		Young, plain.	Young, banded.	Total.
Oopu. . . . .	36	32	88.8	41	27	68	1.89	2.12	Adults:			
Apirimaue.	6	4	66.6	3	3	6	1.50	1.00	Plain. . . . .	22	1	23
									Banded. . . .	..	4	4
									Total. . . . .	22	5	27

#### THE MENDELIAN INHERITANCE OF THE COLOR-PATTERN.

In the foregoing specific descriptions of the several colonies of *affinis*, two principal types of coloration have been found in almost all cases, namely, the so-called *plain* and the *banded*; the former is always more numerous represented, and sometimes it is the exclusive kind, even in cases where several hundreds of snails have been taken, as in Papenoo. The genetic interrelationships of the main color-classes, where both occur in the same association, are demonstrated by the data of inheritance, heretofore presented in a tabular form which shows to what extent the young snails produced by one type of parent represent the same class or display the alternative form of coloration.

Now it is desirable to treat the observed facts in another way, to see if a Mendelian order of heredity is followed by the plain and banded characters, viewed as alternatives. The problem, then, is precisely the same as in the earlier case of *rubescens*, where the contrasted yellow and red colors were considered. Likewise the same difficulties are encountered, especially that arising from the low average numbers of young produced by the gravid adults. In very few instances do the banded adults constitute a satisfactorily large percentage of the population, and when they do, their offspring are relatively few; yet the method devised in dealing with *rubescens*, when employed in the favorable cases here, gives results that are in general accordance with the Mendelian interpretation, even though they can not be considered as finally established, for until or unless actual breeding experiments can be carried out the last proof can not be given.

The colonies of only five valleys offer favorable material, namely, those of Tuauru, Farapa, Papeiha, Utuufai, and Faone. In Paraura the banded type forms a considerable percentage of a large collection, but the data are such as to indicate a late appearance of the bands; therefore the young snails of this kind can not be recognized as such. The Tehoro colony must be eliminated because the *anomala* form of coloration is not a striped or banded type; the others are useless for one

reason or another. Confining our attention to the five available cases, clearly each must be taken by itself, for the relative numbers of DD, DR, and RR adults in their populations must be so diverse as to preclude their union into one series.

#### TUAURU VALLEY.

The fundamental facts are that the plain adults amount to 73.2 per cent of the population, and the banded adults to 26.7 per cent, taken as 27 per cent; one of these divisions must be RR, and the other must include DD together with DR. As it happens, the banded pattern seems to be recessive, as in the case of Lang's breeding experiments with *Helix*; so the analysis will first be made on that assumption for *Partula*, although the results that follow from the contrary supposition will be worked out, to be contrasted with the first-found figures.

When the parents bearing young are classified according to their contents, the numbers are the following:

- (1) Plain adults: plain young, 175; both kinds, 10; banded young, 20=205
- (2) Banded adults: plain young, 14; both kinds, 2; banded young, 30=46

We begin with (2) and, assuming that the parents are themselves RR in composition, their mates would have been RR in 27 per cent of the 46 cases, or in 12 instances; this figure differs from the empirical number by 18, which is to be transferred to the middle class, because that excess represents the RR individuals mated with DR which have only a single offspring and hence can not display the two expected kinds of plain and banded young. Making a correction of the figure for the first group, to the same degree of  $\frac{18}{30}$ , we obtain:

- (3) Banded adults: plain young, 6; both kinds, 28; banded young, 12=46

Hence the three kinds of mates of the 46 RR parents, and the three kinds of snails in the whole population, would be DD 6, DR 28; RR 12.

Testing this in the case of the plain parents of (1), making a correction of the first figure to the empirically defined extent of  $\frac{18}{30}$ , the actual numbers are: plain young 70, both kinds 135, as compared with the expected numbers: plain young 58, both kinds 147. The difference is 12 out of 205, or 5.8 per cent.

When the contrary assumption is made, namely, that the plain coloration is recessive to banding, the proportions of DD:DR:RR come out as 6:144:55. Testing these relations in the independent class of banded snails, assumed to be DD+DR, the empirical figures (plain young 3, both kinds 43) depart from the expectation of 9.5:36 to the extent of 6.5 out of a series of 46, or 14.1 per cent. The former assumption seems to be more justified by the *Partula* data themselves, as well as by the analogous results of Lang for *Helix*. •

#### FARAPA VALLEY.

Here the red-banded and 'brown-banded snails are combined into one group, to be contrasted with the unbanded class of whatever ground-color, for the problem deals only with bands and their absence. The figures for the general population



of 591 are: plain adults 76.3 per cent, banded adults 23.6 per cent, taken as 24 per cent. The gravid adults with distinguishable young are as follows:

Plain adults: plain young 296; both kinds, 8; banded young, 13 = 317

Banded adults: plain young, 28; both kinds, 10; banded young, 39 = 77

Proceeding first on the assumption that banding is recessive, the proportions of the DD, DR, RR mates of the RR adults come out as 13:46:18, the corrections to be made amounting to  $\frac{21}{39}$  of the first and third figures as given above. When these relations are assumed in an analysis of the plain parents, the expected number of adults with plain young and adults with both kinds are 112 and 205, respectively, as compared with the empirical corrected figures of 137 and 180, a difference of 25 out of 317, or 7.8 per cent.

On the contrary assumption, when the proportions of DD:DR:RR are worked out from the plain series, and tested for the 77 banded adults, the departure of the observed facts from expectation amounts to 10.4 per cent, and is thus greater than in the alternative case.

#### PAPEIHA VALLEY.

This association is the least favorable of the five, apparently on account of the relatively small numbers of the banded adults, which constitute only 8.5 per cent of a series of 163. Nevertheless, the agreements between expectation and observation are remarkably close on the assumption that banding is recessive. The gravid parents, when classified as to their embryonic contents, are:

Plain adults: plain young, 75; both kinds, 0; banded young, 3 = 78

Banded adults: plain young, 3; both kinds, 1; banded young, 3 = 7

From the second line, the proportion of DD, DR, and RR mates come out as 1:5:1. Using these figures for an analysis of the plain adults, the expected numbers of adults with plain young would be 22, while those with both kinds of young should be 56; the actual numbers, with the adjustments made, are 25 and 53, a difference of only 3 out of 78, or 3.8 per cent. On the contrary assumption, the proportions of DD:DR:RR would be 3:4:71, which seem absurd on inspection; the figures can not be tested for the other series on account of the small numbers involved.

#### UTUUFAL VALLEY.

In a population made up of 79 per cent plain and 21 per cent banded, the parents with classified young are the following:

Plain adults: plain young, 94; both kinds, 2; banded young, 9 = 105

Banded adults: plain young, 6; both kinds, 0; banded young, 17 = 23

Without retailing the steps in the process of analysis, simply the results may be stated. On the assumption that banding is recessive, the proportions of DD:DR:RR prove to be 2:9:12; the independent test for the plain parents with plain young and parents with both kinds as 26.5 and 78.5, respectively, in theory, as compared with 28 and 77 as deduced from the observations. The difference is 1.5 in 105, or 1.4 per cent, whereas on the contrary assumption the difference amounts to 26.1 per cent.

## FAONE VALLEY.

In this last case the plain adults amount to 88 per cent of the population. The classified gravid parents are as follows:

Plain adults: plain young, 175; both kinds, 0; banded young, 8=183  
Banded adults: plain young, 18; both kinds, 2; banded young, 15=35

Here the average number of young is little over 1 to each fecund adult, and hence a larger correction has to be made in dealing with the figures of the second line. The proportions of DD, DR, and RR are 4, 28, and 3, respectively, when the first assumption is made, when the difference between the empirical and expected figures for the first line amounts to 6 out of 183, or 3.3 per cent. On the second hypothesis, namely, that the absence of bands is recessive, the proportion of DD, DR, and RR are the clearly unnatural ones of 1:21:161, and the departure of actual from expected figures is 2 in 35, or 5.4 per cent. Here again the first assumption gives more credible and consistent results.

In brief, the facts indicate (1) that the absence of bands is dominant to their presence, and (2) that a Mendelian order of inheritance is followed by these alternative characters.

## SUMMARY AND CONCLUSION.

Bringing together the principal results of the foregoing detailed studies in order to emphasize the general features of significance, almost the same statements must be made as in the case of *rubescens*, for the fundamental principles of distribution and variation are essentially similar in nature and meaning. The material is more complicated, however, through the sporadic occurrence of sinistral mutants among the predominant dextral snails, whereas *rubescens* is invariably sinistral, while the variations in coloration are more numerous and more sharply distinguished than in the case of the contrasted variety. We need not now deal with the extrinsic relations of *affinis*, for these are best considered in a review of the whole species at a later point; at present, the intrinsic features are the objects of attention.

I. *As a primary variety, affinis is distinguished by its dextral coil, small size, and brownish coloration, but it is not invariable in these respects.* Sometimes it is reversed, and in some localities the shells are much above the average in size, while here and there the red coloration is displayed by occasional individuals or by a large proportion of the colony, as in Farapa. It occupies essentially the same territory as in the earlier decades, when Garrett made his studies.

II. *The colonies of affinis vary in their make-up as regards the relative numbers in the whole Partula population and in the otaheitana population, as well as in the proportionate numbers of dextral and sinistral components and of the constituent color-classes.* Such variations may not be referred to diverse environmental conditions; *P. hyalina* and *P. clara* exist in the same areas as they do elsewhere; *rubescens* accompanies *affinis* in nearly all of its valleys, while *sinistrorsa* is its associate in some parts of Taiarapu. Yet these other types do not display the complex of characters that distinguish *affinis*.

III. *The dimensional characters of the shells vary from valley to valley, without any consistent relation to geographical or other external conditions.* The pertinent data are presented in summary numerical form (tables 157 and 158) and in graphic diagrams (table 159), so that the degree, relation, and direction of changes noted in passing from one area to another may be readily comprehended. It is unnecessary to supplement the tabulations by verbal statements.

TABLE 157.—*Partula otaheitana affinis*. Statistical summary, dextral representatives. Mean value.

Valley.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
		<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>p. ct.</i>	
Tuauru...	354	17.3814±.0282	10.3232±.0153	59.3220±.0759	9.3181±.0169	7.3091±.0125	78.3870±.0936	53.4944±.0671	2.8650±.0249
Ahonu...	143	17.0136±.0469	10.0608±.0277	59.0105±.1114	9.0147±.0297	6.9308±.0227	76.7727±.1406	52.8217±.1077	2.4759±.0756
Faaripoo...	308	16.7263±.0276	9.8987±.0160	59.0617±.0764	8.9701±.0167	6.8149±.0129	75.8312±.1015	53.5130±.0710	2.0839±.0429
Papenoo...	147	16.6235±.0462	9.6986±.0242	58.2143±.1266	8.9109±.0242	6.6442±.0205	74.3299±.1558	53.4864±.1034	1.5164±.0507
Farapa...	582	17.8227±.0265	10.2945±.0122	57.7423±.0632	9.4185±.0133	7.2172±.0094	76.5638±.0744	52.7320±.0485	1.1439±.0123
Faarumai...	313	15.5388±.0245	9.2668±.0132	59.5767±.0748	8.1741±.0142	6.4163±.0107	78.4041±.0907	52.5191±.0713	2.4154±.0341
Tiarei...	151	16.2222±.0377	9.3013±.0200	57.1424±.1104	8.3675±.0211	6.3662±.0174	76.0364±.1316	51.4404±.0903	2.4702±.0459
Mahaena...	137	16.6989±.0414	9.6985±.0204	58.0620±.1249	8.7555±.0227	6.8314±.0176	77.9818±.1341	52.3540±.1055	3.0073±.0459
Vahii...	407	16.6546±.0245	9.9285±.0128	59.4803±.0659	9.0091±.0140	6.9708±.0106	77.3256±.0780	53.9545±.0569	2.3793±.0420
Paraura...	573	16.3071±.0206	9.6578±.0106	59.1230±.0619	8.6557±.0118	6.6742±.0090	77.0113±.0654	52.9538±.0505	2.0000±.0255
Faatautia...	12	16.1750±.1171	9.3667±.0331	57.9167±.4011	8.2333±.0507	6.6334±.0331	79.4166±.4733	50.7500±.1799	3.4166±.1655
Papeiha...	162	16.8463±.0356	9.7852±.0195	58.0247±.1114	9.0086±.0222	6.7358±.0165	74.6667±.1344	53.3457±.0963	2.7117±.0527
Utuufai...	338	16.6645±.0278	9.7970±.0141	58.6893±.0778	8.7911±.0151	6.7189±.0120	76.3491±.0888	52.6124±.0596	3.2843±.0339
Faone...	587	16.4892±.0207	9.6997±.0110	58.7334±.0582	8.6792±.0113	6.6693±.0087	76.7743±.0645	52.5290±.0479	3.1271±.0286
Tehoro...	303	16.0382±.0259	9.4201±.0128	58.7013±.0828	8.4802±.0137	6.4604±.0096	76.0776±.0904	52.8201±.0713	3.3049±.0330
Haavini...	56	15.6821±.0664	9.3215±.0338	59.3571±.1968	8.4250±.0395	6.3500±.0288	74.3750±.1763	53.5357±.1762	1.8750±.0703
Tautira...	205	15.9880±.0374	9.3098±.0190	58.3049±.1088	8.3644±.0191	6.2756±.0148	74.9342±.1031	52.1976±.0817	1.1933±.0262
Aionifaa...	14	16.0143±.0984	9.2149±.0575	57.2858±.2064	8.3286±.0744	6.2000±.0447	74.2143±.3436	51.7857±.2925	1.0714±.0464
Aiurua...	100	15.5810±.0436	9.1100±.0217	58.3500±.1472	8.1820±.0227	5.9780±.0161	72.9500±.1448	52.3600±.1129	1.0400±.0016
Vaiau...	11	15.5408±.1383	9.0273±.0834	58.0455±.3613	7.9909±.0903	6.1909±.0437	77.3181±.5333	51.4091±.2796	3.0909±.2203
Hototunu...	45	16.4500±.0744	9.6378±.0434	58.5666±.1982	8.6067±.0446	6.3667±.0303	73.9000±.2448	52.2111±.1691	1.0217±.0144
Vaiaaia...	5	16.3700±.2896	9.7000±.1790	58.9000±.6497	8.7000±.1663	6.5000±.1207	74.5000±.5406	52.9000±.1478	1.6000±.2413
Vavii...	6	15.9500±.2979	9.2000±.0885	58.0000±.5379	8.2000±.0993	6.0667±.1120	74.1667±.3785	51.5000±.3555	1.5000±.2103
Vaipoe...	69	16.5457±.0643	9.5580±.0351	57.6014±.1829	8.7811±.0355	6.3406±.0263	72.1812±.2080	52.9348±.1603	2.1884±.0866
Haoma...	44	16.8432±.0790	10.1273±.0413	60.0909±.2160	8.8409±.0510	6.9636±.0371	78.5909±.3140	52.5227±.1908	3.3181±.0711
Oopu...	36	16.7583±.0770	9.8278±.0474	58.8889±.2074	8.8889±.0510	6.7389±.0317	75.8445±.2496	52.8611±.1381	2.4167±.1197
Apirimaue...	6	17.7500±.1262	10.1333±.1164	57.1667±.5877	9.0667±.0805	6.8000±.0693	74.5000±.4205	51.0000±.3711	1.6667±.1298

IV. *Mutations of several kinds have arisen in certain areas.* Sinistral individuals were found by Garrett only in Papenoo, while in my experience they now occur in seven valleys. Banded types were described by Garrett for a restricted locality, whereas they are now to be found in twenty separated regions, in which they prove to be closely related to their plain associates. In Farapa a red-banded form exists, and in northeast Taiarapu an entirely new bicolored pattern is exhibited by some of the shells. A giant adolescent was discovered in Paraura. In all of these cases, the significant point is that the mutants, for such these seem to be, have appeared in the old and long-occupied territory, in which environmental changes of a causative nature would not be likely to occur.

V. *A Mendelian order of inheritance seems probable in the case of the alternative plain and banded forms of coloration, the former being dominant to the latter.* The facts as observed and interpreted lead to this conclusion, although the difficulties in the way of final proof are such as to render the statement tentative only.

TABLE 158.—*Partula otaheitana affinis*. Progressive comparison of dextral representatives. Differences in mean value.

	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index.
	Length.	Width.	Proportions.	Length.	Width.	Proportions.		
Tuauru...	<i>mm.</i> -0.3678±.0547	<i>mm.</i> -0.2624±.0316	<i>p. ct.</i> -0.3115±.1344	<i>mm.</i> -0.3034±.0342	<i>mm.</i> -0.3783±.0259	<i>p. ct.</i> -1.6143±.1690	<i>p. ct.</i> -0.6727±.1269	-0.3891±.0796
Ahonu...	- .2873±.0544	- .1621±.0320	[+ .0512±.1350]	[- .0446±.0341]	- .1159±.0261	- .9415±.1731	+ .6913±.1290	- .3920±.0869
Faaripoo...	[- .1028±.0538]	- .2001±.0290	- .8474±.1478	- .0592±.0294	- .1707±.0242	- 1.5013±.2111	[- .0266±.1254]	- .5675±.0664
Papenoo...	+1.1992±.0533	+ .5959±.0271	- .4720±.1608	+ .5076±.0276	+ .5730±.0225	+2.2339±.1995	- .7544±.1142	- .3725±.0522
Farapa...	-2.2839±.0361	-1.0277±.0180	+1.8344±.0979	-1.2444±.0194	- .8009±.0142	+1.8403±.1173	- .2129±.0862	+1.2715±.0362
Faarumai...	+ .6834±.0449	[+ .0345±.0239]	-2.4343±.1333	+ .1934±.0254	- .0501±.0204	-2.3677±.1598	-1.0787±.1150	[+ .0548±.0572]
Tiarei...	+ .4767±.0560	+ .3972±.0286	+ .9196±.1667	+ .3880±.0310	+ .4652±.0247	+1.9454±.1879	+ .9136±.1387	+ .5371±.0649
Mahaena...	[- .0443±.0481]	+ .2300±.0241	+1.4183±.1412	+ .2536±.0267	+ .1394±.0205	- .6562±.1551	+1.6005±.1199	- .6280±.0622
Vahii...	- .3475±.0320	- .2707±.0166	- .3573±.0904	- .3534±.0183	- .2966±.0139	- .3143±.1018	-1.0007±.0761	- .3793±.0491
Paraura...	[- .1321±.1189]	- .2911±.0347	-1.2063±.4058	- .4224±.0520	[- .0408±.0343]	+2.4053±.5721	-2.2038±.1868	+1.4166±.1655
Faatautia...	+ .6713±.1264	+ .4185±.0384	[+ .1080±.4163]	+ .7753±.0553	+ .1024±.0370	-4.7499±.5841	+2.5957±.2040	- .7049±.1737
Papeiha...	- .1818±.0452	[+ .0118±.0241]	+ .6646±.1358	- .2175±.0268	[- .0169±.0204]	+1.6824±.1611	- .7333±.1132	+ .5726±.0626
Utuufai...	- .1753±.0346	- .0973±.0179	[+ .0441±.0971]	- .1119±.0188	- .0496±.0148	+ .4252±.1097	[- .0834±.0765]	- .1572±.0443
Faone...	- .4510±.0331	- .2796±.0168	[- .0321±.1012]	- .1990±.0178	- .2089±.0129	- .6967±.1110	+ .2911±.0859	+ .1778±.0448
Tehoro...	- .3561±.0713	- .0986±.0361	+ .6558±.2137	[- .0552±.0418]	- .1104±.0303	-1.7026±.1981	+ .7156±.1901	-1.4299±.0777
Haavini...	+ .3059±.0762	[- .0117±.0388]	-1.0522±.2251	[- .0606±.0439]	- .0744±.0324	+ .5592±.2042	-1.3381±.1942	- .6817±.0750
Tautira...	[+ .0263±.1053]	[- .0949±.0606]	[-1.0191±.5413]	[- .0358±.0768]	[- .0756±.0471]	[- .7199±.3587]	[- .4119±.3037]	- .1219±.0533
Aionifaa...	- .4333±.1076	[- .1049±.0615]	+1.0642±.2535	[- .1466±.0778]	- .2220±.0475	-1.2643±.3728	[+ .5743±.3260]	[- .0314±.0464]
Aiurua...	[- .0402±.1450]	[- .0827±.0862]	[- .3045±.3901]	[- .1911±.0931]	+ .2129±.0466	+4.3681±.5526	- .9509±.3015	+2.0509±.2203
Vaiau...	+ .9092±.1570	+ .6105±.0940	[+ .5211±.4121]	+ .6158±.1007	+ .1758±.0555	-3.4181±.5868	+ .8020±.3267	-2.0692±.2208
Hototunu...	[- .0800±.2990]	[+ .0622±.1842]	[+ .3334±.6792]	[+ .0933±.1722]	[+ .1333±.1245]	[+ .6000±.5934]	+ .6889±.2246	+ .5783±.2417
Vaiaaia...	[- .4200±.4153]	- .5000±.1996	[- .9000±.8435]	- .5000±.1937	- .4333±.1674	[- .3333±.6674]	-1.4000±.3850	[- .1000±.3201]
Vavii...	[+ .5957±.3247]	+ .3580±.0952	[- .3986±.5681]	+ .5811±.1054	[+ .2739±.1694]	-1.9855±.4319	+1.4348±.3898	+ .6884±.2274
Vaipoe...	+ .2975±.1019	+ .5693±.0542	+2.4895±.2830	[+ .0598±.0621]	+ .6230±.0455	+6.4097±.3766	[- .4121±.2492]	+1.1297±.1120
Haoma...	[- .0849±.1103]	- .2995±.0629	-1.2020±.2994	[+ .0480±.0721]	- .2247±.0488	-2.7464±.4016	[+ .3384±.2479]	- .9014±.1392
Oopu...	+ .9917±.1478	+ .3055±.1256	-1.7222±.6232	[+ .1778±.0953]	[+ .0611±.0762]	-1.3445±.4894	-1.8611±.4034	- .7500±.1766
Apirimaue...								

VI. The combined statistics for the several colonies provide a basis for comparing *affinis* with the other major divisions of *Partula otaheitana*. Effecting the combination in the two ways earlier explained, the results are presented in table 160; the figures refer to the dextral representatives only, for the sinistral snails are too few and too scattered to be similarly treated.

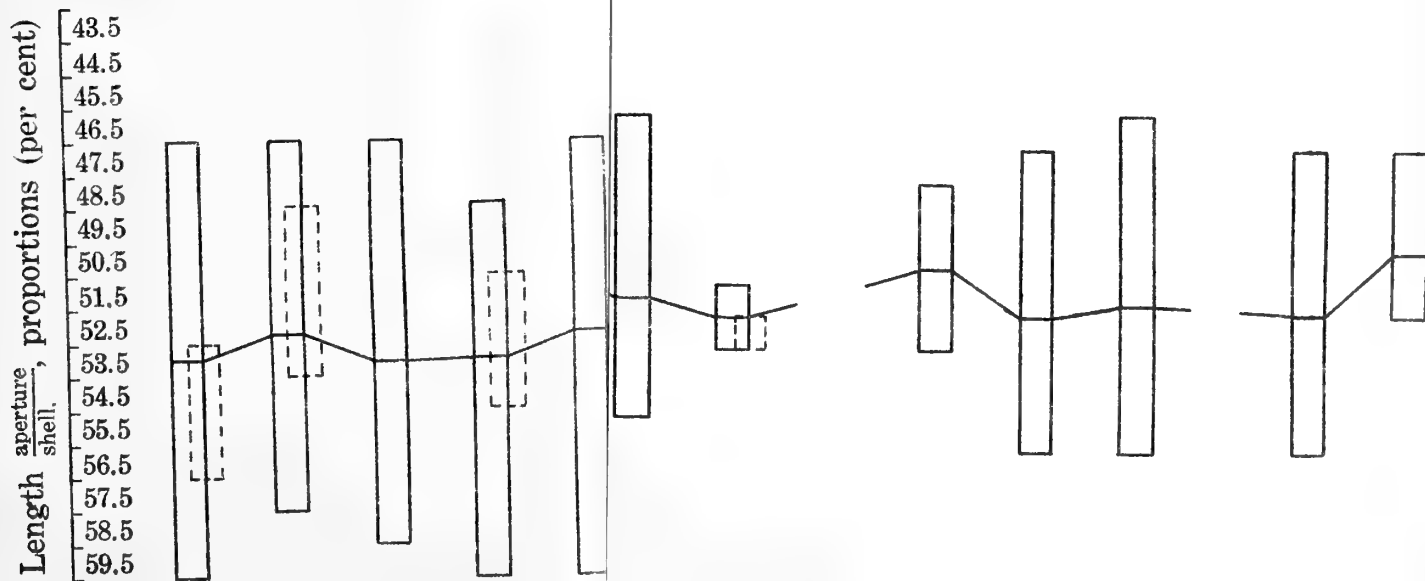
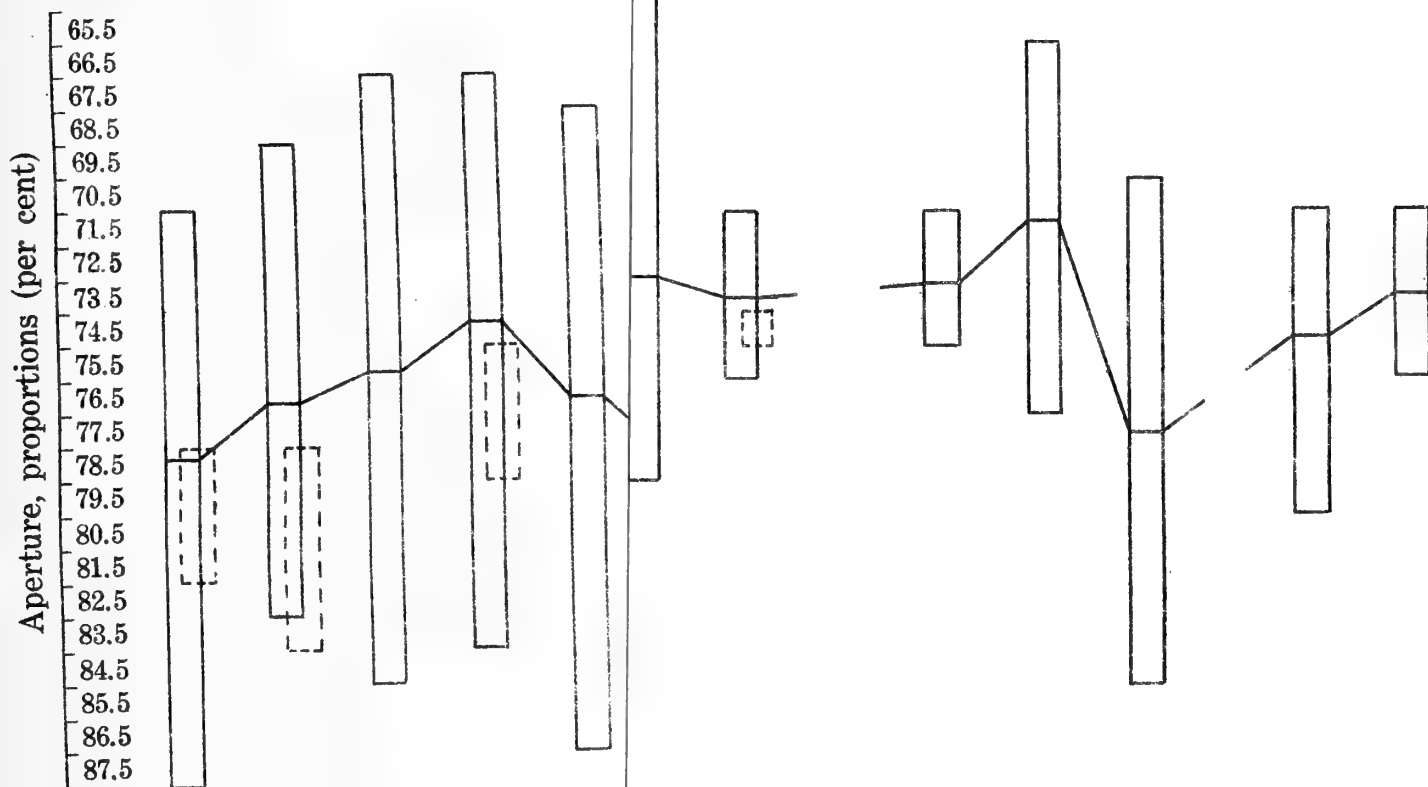
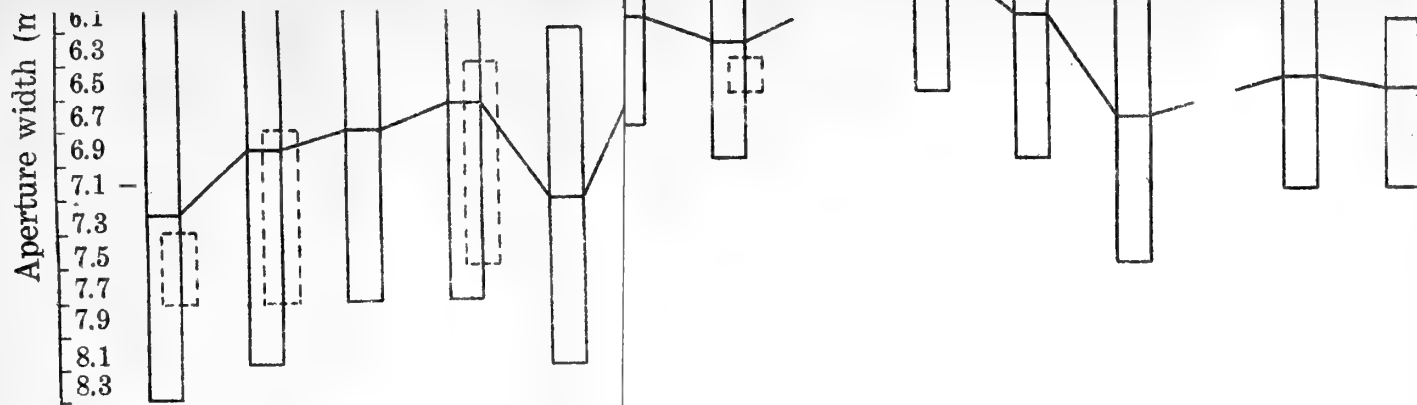




TABLE 159. *Partula otaheitana affinis*. Progressive variation in range and mean value.  
(Dextral shells, full lines; sinistral, interrupted lines.)

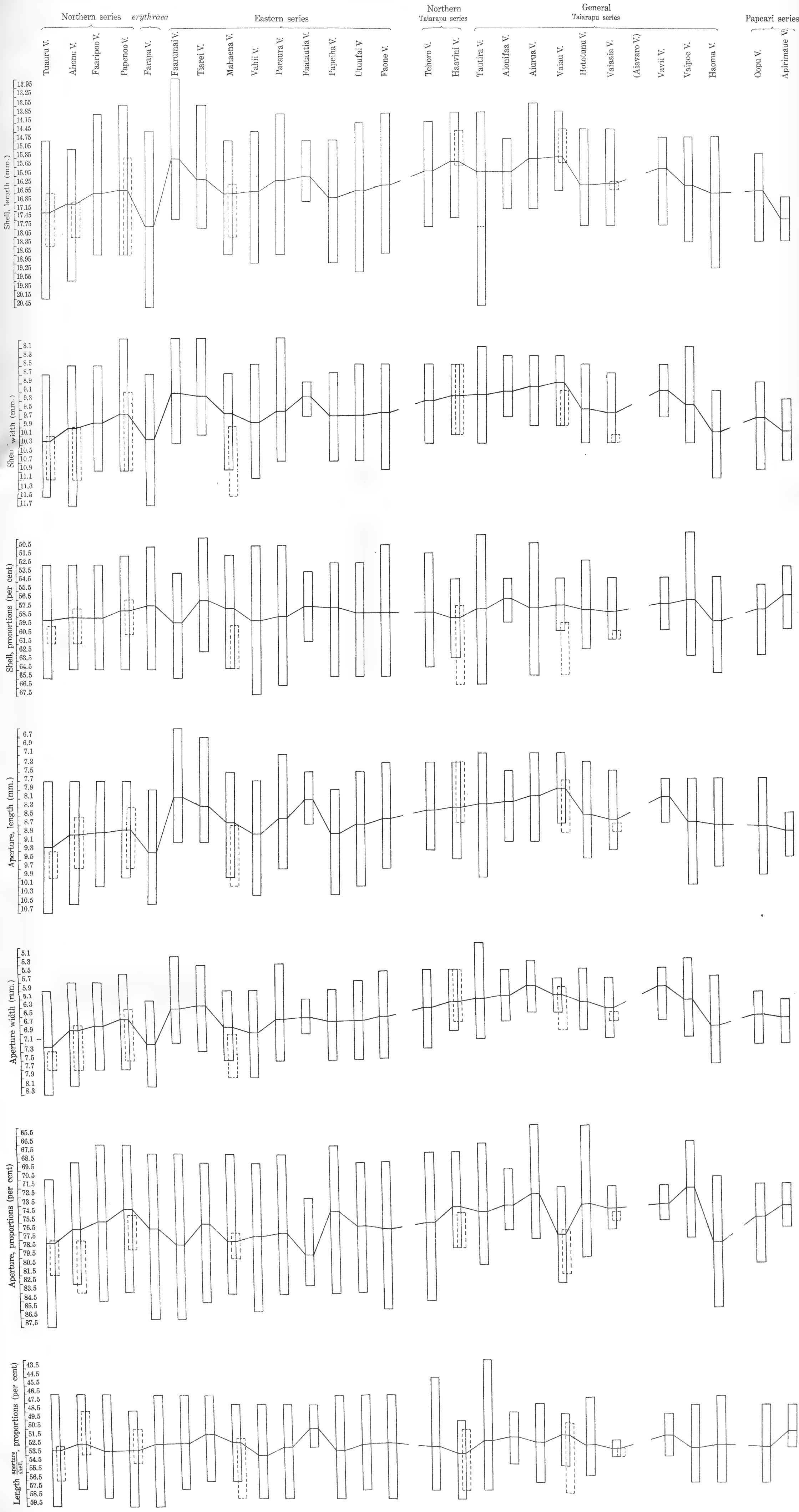






TABLE 160.—*Partula otaheitana affinis*. Summary description of dextral individuals.<sup>1</sup>

Character.	Mean value.		Standard deviation.	
	Combined series.	Average of valley types.	Combined series.	Average of valley types.
Shell, length, mm.....	16.6187±.0092	16.4690	0.9770±.0065	0.7394
width, mm.....	9.7068±.0049	9.6431	.5236±.0035	.3902
proportions, p. ct.....	58.7047±.0209	58.4948	2.2150±.0148	2.0545
Aperture, length, mm.....	8.8076±.0052	8.6726	.5562±.0037	.4172
width, mm.....	6.7488±.0042	6.5987	.4492±.0030	.3099
proportions, p. ct.....	76.5190±.0261	75.9038	2.7678±.0185	2.3266
Length aperture ÷ length shell, proportions, p. ct. ....	52.8743±.0175	52.5387	1.8584±.0124	1.6384
Tooth, index.....	2.3125±.0071	2.2290	.7260±.0050	.7726

<sup>1</sup>Number is 5,114, for all characters excepting the tooth, for which the number is 4,755.

## PARTULA OTAHEITANA SINISTRORSA Pease.

## GENERAL DESCRIPTION.

Each of the primary varieties hitherto distinguished and described exhibits some degree of internal differentiation, but none displays the remarkable complexity of the triple series whose first section is now to be taken up, the series which, for reasons that will appear, must be designated as the *sinistrorsa-sinistralis-crassa* series. In the valleys located in the southern and western parts of Tairapu and Tahiti nui the snails belonging to *P. otaheitana* differ from other primary forms and agree collectively in certain distinctive attributes. They are sinistral in coil, although here and there dextral individuals occur singly, or at times in considerable numbers. They display ground-colors of various shades of brown; the rich yellow and red of *rubescens* are lacking, save in certain very sharply localized associations in the western sector. In pattern they are of two general kinds, namely, banded and unbanded. Great variability in size occurs, for some shells are as small as *affinis*, while others are as large as the biggest *rubescens*; the shape also varies from stout to slender. The tooth is highly variable, some colonies possessing it in large degree, while others are devoid of it.

Taken as a whole, this southern and western series of associations constitutes a primary division of *Partula otaheitana* in the sense that its constituents are collectively distinguishable from *P. o. rubescens*, *P. o. affinis*, etc., while they possess the basic characteristics of the species *otaheitana*. Yet its differentiation is such that three main sections can be readily recognized that differ *inter se*, it is true, but their differences are less than those which separate primary varieties from one another.

The characteristic examples of these three sections, like those of the primary varieties already discussed, were first described and named as distinct species, namely, *P. sinistrorsa*, *P. sinistralis*, and *P. crassa*. Their territories adjoin in geographical order from east to west and north, without overlapping, although *P. o. affinis* occurs in some valleys that are occupied by *sinistrorsa*. Garrett and others have recognized the *otaheitana* nature of these forms and have subordinated them to the same rank as *rubescens*, etc. But in so far as they collectively differ

from the other primary varieties, they constitute a division with a status equivalent to that of the latter. However, in order to avoid the establishment of too many taxonomic terms, the group as a whole will be called simply the sinistral series of the south and west, while its three components will be specified by their original names, *P. o. sinistrorsa*, *P. o. sinistralis*, and *P. o. crassa*. They will be treated in this order, as so many subspecies.

Each of these divisions, in its turn, is differentiated into subordinate parts, on the basis of colonial characters that are sometimes entirely unique for a given valley, and sometimes are shared by the associations of a short series of adjoining localities. Hence any one of these three divisions is quite as complex as *P. o. affinis* itself, or another primary variety.

Obviously, then, we are confronted with an extremely heterogeneous *otaheitana* population, and with attendant difficulties in the way of analyzing and describing it. But the difficulties may be avoided in greater part, and the situation may be more clearly comprehended, if it be borne in mind that *sinistrorsa*, *sinistralis*, and *crassa* are three parts of *P. otaheitana* that resemble one another more than any one of them resembles a contrasted primary variety.

Garrett's statements regarding this series are more than ever important, in view of the intrinsic interest of the snails themselves as well as on account of the geographical facts. He says (pp. 49, 50):

"Pease's *sinistrorsa* is confined to the south coast of Tahiti proper, where it exists in the greatest profusion in all the valleys and lowland forests for a distance of ten or twelve miles. In the valley which is the limit of the range of the dextral *affinis* [Apirimaue, then as now] I took several specimens of the sinistral *sinistrorsa*. The latter is invariably reversed, dentate or edentate, fulvous with three more or less diffused reddish chestnut bands. Reeve figures the same shell on Plate 3, figure 13a, as *Otaheitana*. Bandless varieties are frequent, and vary from straw yellow to fulvous or light chestnut, frequently strigated and the lip white. The latter varieties differ none from the true *Otaheitana* of Fautana [Fautaua]. \* \* \*

"It is worthy of remark that in that part of the district of Papieri [Papeari] occupied by *sinistrorsa* is also the headquarters of the terrestrial *P. producta*, a dextral species which is always edentate, and exhibits the fasciation of the former.

"After passing to the westward of the range of the typical *sinistrorsa*, which presents the same features for a distance of ten or twelve miles, it suddenly exhibits a tendency to a change in its becoming more stunted, more solid, always dentated, and the bands, one to three, are sharply defined on a pale ground. It is the *sinistralis* of Pease, ms., and occupies two valleys.

"In the next large valley, called Faahuaite [Orofere], on the southeast coast, we find 'Pease's' *crassa* (ms.), which is also a sinistral shell, always dentated, solid, more tightly coiled than *sinistrorsa* and the body whorl is more flattened. It is rarely marked by a single narrow submedian chestnut band. In the same valley, but more inland, occurs a smaller form, which is, I suppose, the *P. brevicula* Pse., ms.

"The following valley, named Punaavia [Punaruu], is the metropolis of the beautiful *P. nodosa*, which also exhibits three bands. Far above the restricted range of the latter, where the valley turns towards the head of Fantana [Fautaua] the home of the typical *Otaheitana*, I took a few examples of a *Partula*, similar to, but larger than, *crassa*. The next valley in the habitat of *lignaria*."

Even in advance of the detailed analysis of this series, certain points of the foregoing quotation must be discussed. Pease's *sinistrorsa* is not now confined to Tahiti nui, as four valleys of Taiarapu are inhabited by it; it displays more types of coloration than are enumerated. Furthermore, *sinistrorsa* is not *invariably reversed*; that Garrett makes his categorical statement is very important as indicating a situation in his time which has materially changed since. There is little chance of confusing *P. producta* with dextral sports from the reversed *sinistrorsa* stock, because the details of fasciation differ distinctly and other diverse qualities of the two kinds are readily found. Finally, *sinistrorsa* does not present identical features in the valleys of its range, save in the most general way; in color composition of the colonies and in details of size and form, considerable diversity exists.

Comment on the statements relating to *sinistralis* and *crassa* may be deferred until those divisions are met in the regular order of description.

TABLE 161.—*Partula otaheitana sinistrorsa*. Census of the variety.

Valley.	Total No. of adults.	Number in adult population.						Per cent of adult population.					
		Sinistral.			Dextral.			Sinistral.			Dextral.		
		apex.	cestata.	phæa.	apex.	cestata.	phæa.	apex.	cestata.	phæa.	apex.	cestata.	phæa.
Vaiaia.....	139	56	78	5	..	...	...	40.3	56.1	3.6	...	....	....
Aiavaro.....	170	37	133	...	..	...	...	21.8	78.2	....	...	....	....
Vavii.....	219	...	219	...	..	...	...	...	100	....	...	....	....
Vaipoe.....	190	14	176	...	..	...	...	7.3	92.6	....	...	....	....
Haoma.....	0	...	...	...	..	...	...	...	...	....	...	....	....
Oopu.....	0	...	...	...	..	...	...	...	...	....	...	....	....
Apirimaue...	284	16	264	4	..	...	...	5.6	92.9	1.4	...	....	....
Titaviri.....	245	27	115	26	<sup>1</sup> 0	15	62	11.0	46.9	10.6	...	6.1	25.3
Tenaire.....	907	193	109	72	51	124	358	21.3	12.0	8.0	5.6	13.6	39.4
Maara.....	203	7	76	50	5	36	29	3.4	37.4	24.6	2.5	17.7	14.3
Vaihiria.....	303	...	277	26	..	...	...	...	91.4	8.6	...	....	....
Vairaharaha..	247	...	52	195	..	...	...	...	21.0	78.9	...	....	....
Faarahi.....	467	...	165	300	..	1	1	...	35.3	64.2	...	0.2	0.2
Moaroa.....	434	...	171	263	..	...	...	...	39.4	60.6	...	....	....
Taharua.....	325	...	115	207	..	3	...	...	35.4	63.6	...	0.9	....
Total.....	4,133	350	1,950	1,148	56	179	450	8.5	47.2	27.8	1.3	4.3	10.9

<sup>1</sup>One adolescent.

The absolute and relative members of *sinistrorsa* in the *otaheitana* populations of its range have been given at an earlier point. Three subordinate color-types are specified in the following description as apex, cestata, and phæa; their absolute and relative abundance in both the sinistral adult group and in the dextral adult group, when this is represented, are given in table 161. The details will be treated in serial order.

It remains only to state that the range of *sinistrorsa* is divided into two geographical regions, viz, the southern and western part of Taiarapu, and the southern valleys of Tahiti nui to and including Taharua. In the isthmus of Taravao *sinistrorsa* does not appear, nor in the adjacent valleys of Haoma in Taiarapu and Oopu in Tahiti nui; a single immature specimen was taken in Faone Valley, the southernmost habitable area of Partulæ in the eastern quadrant.

## THE COLONIES OF TAIARAPU.

The collections taken in the isthmus of Taiarapu possess an unusual degree of interest, both on account of their own peculiar qualities and also because this part of Tahiti was formerly uninhabited by *otaheitana* of the *sinistrorsa* series. The latter point is clear from two facts: first, that Garrett describes the range of *sinistrorsa* as beginning with that valley in the southeastern part of Tahiti nui where *affinis* stops, *i. e.*, Apirimaue; second, that the map drawn by Garrett and published in Hartman's paper omits *sinistrorsa* from the peninsula, while it correctly locates the other species and varieties, some of which fall below *sinistrorsa* in numbers at the present time. Obviously, then, members of this group now under consideration must have entered Taiarapu in recent decades. Whether their present occupation of the new territory is due to their own migratory efforts, or has been brought about by human transport, can not be determined with certainty, for there are conflicting evidences on this matter. The primary fact is, however, that they now occur in a region which was devoid of them formerly; their peculiar features are scarcely less interesting than this fundamental datum.

The range begins at the east with Vaiaaia Valley, the second topographical element from the end of the area of habitation of *rubescens*. Passing westward, the valleys are all occupied by flourishing associations of *sinistrorsa* as far as Haoma, which bears *affinis* only. Three color-forms are found in the whole area; in one case all three occur in a colony, in two cases only two, while in the remaining valley a single color-class is present. In their collective characters, the Taiarapu colonies are similar to the nearest ones of the main land-mass. The large size of the shells is their most notable feature.

## VAIAAIA VALLEY.

The easternmost colony of *sinistrorsa* exists in Vaiaaia Valley, where about 150 snails of all ages were taken, in addition to *otaheitana affinis*, *clara*, and *hyalina*. The shells fall into three color-classes, which, for the sake of brevity and clearness, will be given technical names. This procedure does not imply that any of these names has the value or significance of a term like *affinis* or *sinistrorsa* itself, which are group-designations; they are parallel to *pallidior*, etc., in the case of *P. nodosa*, and are to be used as brief substitutes for longer phrases or descriptions.

Shells of the first class, *apex* (plate 30, figs. 10 to 12), are bandless, and have basal and penultimate whorls of a light horny yellow color, while the upper whorls are lighter or darker brown with a purplish cast. In a few cases the spire lacks the dark color and is whiter than the lower part of the shell. This kind is represented in the collections of various museums, but its genetic relations to other types have never been defined, because no previous investigation has taken into account the data on the heredity of varietal characters. The second color-type, *cestata*, is the characteristic one of this primary variety; on a yellowish-horny ground-color three distinct revolving bands of a rich dark brown encircle the whorls (plate 30, figs. 13 to 16). The sutural band is not wide, but the median stripe is invariably broad and zonate and is often more sharply defined than the others. At the base of the

shell is the third band, which is more frequently vague as to its limits. The lip is usually stained with brown or purplish brown. Some suffusion of the bands takes place on the last whorl in many instances, although the markings retain their integrity on the spire. The shell shown in figure 15 is in color an exact counterpart of Pilsbry's figure 1, plate 26, assigned to *amabilis*; it has been shown earlier that *amabilis* is *never banded* and that such shells are true *sinistrorsa*. Decortication leads to the whitening of the ground-color, as in figure 13. The third color-class, *phæa*, comprises a few shells that are an almost uniform deep chestnut-brown (plate 30, figures 17 and 18) and have the lip tinted with brown or purple-brown, like the *cestata* shells. Pilsbry has given the name *confluens* to a color-form of *sinistrorsa* which occurs in some of the southern valleys in Tahiti nui; the type existing here somewhat resembles *confluens*, but its uniform and "solid" ground-color is not due to the merging of the revolving bands or of vague strigations, but is *sui generis*. When in later pages it becomes necessary to employ a distinctive name for this particular kind of *phæa*, it will be distinguished as *phæa solida*; until then it will be understood that shells assigned to *phæa* are of this subordinate class.

TABLE 162.—*Partula otaheitana sinistrorsa*. *Vaiaaia Valley*.

MEAN VALUE.								
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.	
		<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>p. ct.</i>
apex. ....	55	20.1446 ± .0672	11.1546 ± .0401	55.3182 ± .1978	10.3582 ± .0424	7.7618 ± .0362	74.7546 ± .2478	51.3909 ± .1669
cestata. ...	77	20.0955 ± .0586	11.2611 ± .0349	55.9285 ± .1509	10.4871 ± .0318	7.8559 ± .0263	75.0065 ± .1897	52.1571 ± .1113
phæa. ....	5	20.3300 ± .1354	11.3400 ± .1396	55.5000 ± .3815	10.4200 ± .1645	8.0626 ± .0926	77.1000 ± .9462	51.5000 ± .5594
All. ....	137	20.1237 ± .0430	11.2212 ± .0260	55.6679 ± .1183	10.4328 ± .0257	7.8255 ± .0212	74.9818 ± .1519	51.8212 ± .0962
STANDARD DEVIATION.								
apex. ....	55	0.7391 ± .0475	0.4406 ± .0283	2.1749 ± .1398	0.4666 ± .0300	0.3979 ± .0256	2.7251 ± .1752	1.8357 ± .1180
cestata. ...	77	.7625 ± .0414	.4536 ± .0248	1.9629 ± .1067	.4144 ± .0225	.3421 ± .0186	2.4686 ± .1341	1.4485 ± .0787
phæa. ....	5	.4489 ± .0957	.4630 ± .0987	1.2649 ± .2698	.5455 ± .1163	.3072 ± .0655	3.1369 ± .6690	1.8547 ± .3955
All. ....	137	.7459 ± .0304	.4522 ± .0184	2.0524 ± .0836	.4459 ± .0182	.3689 ± .0150	2.6363 ± .1074	1.6695 ± .0680

At first sight, the form *apex* is much like *rubescens* shells which possess tinted spires, but on further acquaintance their distinctness becomes increasingly apparent; *apex* and *phæa* are bandless, but they are probably no more intimately related to one another than either is to *cestata*.

The shells of all classes are entirely devoid of a columella tooth. In statistical respects (table 162) the three groups are somewhat diverse, *phæa* being the most aberrant. The large dimensions of the shells and of their apertures are notable features.

Fecundity at the time of collection, August, was fairly high (table 163), with a somewhat lower rate for *cestata* than for the other classes.

The data on heredity (table 163) are interesting because all of the young of *cestata* were banded; *apex* produced its own kind and *cestata* young as well, while *phæa*

produced apex and its own type, but no cestata. With a larger series of data it is probable that the third color-type would be found to produce banded young as well. In all cases, the embryonic snails are sinistral.

In brief, then, the Vaiaaia association of *sinistrorsa* comprises three constituent color-types (apex, cestata, and phæa), which are genetically interrelated, always sinistral, and toothless.

TABLE 163.—*Partula otaheitana sinistrorsa*. Vaiaaia Valley.

FECUNDITY.									HEREDITY.			
Series.	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.	Young, apex.	Young, cestata.	Young, phæa.	Total.
apex . . . . .	56	45	80.3	70	31	101	2.24	1.80	9	22	..	31
cestata . . . . .	78	62	79.5	80	51	131	2.11	1.68	..	51	..	51
phæa . . . . .	5	4	80.0	3	6	9	2.25	1.80	3	..	3	6
All . . . . .	139	111	79.8	153	88	241	2.17	1.73	12	73	3	88

## AIVARO VALLEY.

In this region, phæa is lacking in a series of 170 adult *sinistrorsa*; apex is less abundant in relation to cestata than it was in Vaiaaia. The shells illustrated in plate 30, figures 19 to 23, are unusual either in absolute dimensions or in proportionate measures. All are toothless.

TABLE 164.—*Partula otaheitana sinistrorsa*. Aiavaro Valley.

MEAN VALUE.								
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.	
apex . . . . .	36	mm. 20.0417 ± .1009	mm. 11.0334 ± .0446	p. cl. 55.0078 ± .2703	mm. 10.0445 ± .0577	mm. 7.6723 ± .0486	p. cl. 76.3055 ± .3166	p. cl. 50.0078 ± .2312
cestata . . . . .	132	20.1467 ± .0549	11.0864 ± .0256	55.0682 ± .1214	10.0591 ± .0292	7.6637 ± .0220	75.5236 ± .1471	50.3788 ± .0934
All . . . . .	168	20.1250 ± .0483	11.0750 ± .0224	55.0595 ± .1090	10.1202 ± .0261	7.6655 ± .0202	75.6905 ± .1351	50.3036 ± .0889
STANDARD DEVIATION.								
apex . . . . .	36	0.8976 ± .0713	0.3972 ± .0315	2.4050 ± .1911	0.5134 ± .0408	0.4324 ± .0343	2.8168 ± .2239	2.0567 ± .1635
cestata . . . . .	132	.9345 ± .0388	.4363 ± .0181	2.0677 ± .0858	.4977 ± .0206	.3748 ± .0155	2.5059 ± .1041	1.5908 ± .0660
All . . . . .	168	.9278 ± .0341	.4316 ± .0158	2.0950 ± .0771	.5013 ± .0184	.3878 ± .0143	2.5956 ± .0955	1.7087 ± .0628

The colonial statistics (table 164) afford a basis of comparison with the Vaiaaia and other local groups. They show, furthermore, that apex and cestata differ, and the differences are opposite in sign to those observed in the comparison of the same classes in Vaiaaia; the differences in question, however, are not in excess of their probable errors, saving only in the proportions of the aperture. The fundamental question is whether the genetic connection of apex and cestata in each valley is closer than that between apex groups of two neighboring valleys, or between cestata associations from two places; here and hereafter the former is the closer similarity, so far as statistical characters are concerned.

Fecundity in this series is high (table 165) and the larger numbers of embryonic young render the data on heredity (table 165) quite reliable. As in Vaiaia, the *cestata* adults produce only their own kind; *apex* produces very few of its own type in comparison with the numbers of *cestata* young. It may be that there is a Mendelian order of inheritance in the case of the "plain" and the "banded" characters, in which case the large numbers of banded young would indicate that the *cestata* character was dominant, and their *apex* parents would have mated with DD or DR banded *cestata* individuals. It is possible that a secular change in the direction of an entirely banded population is taking place; to settle this point collections should be taken at successive intervals of years.

TABLE 165.—*Partula otaheitana sinistrorsa*. *Aiavaro Valley*.

FECUNDITY.									HEREDITY.		
Series.	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.	Young apex.	Young cestata.	Total.
apex .....	37	30	81.1	40	24	64	2.13	1.73	3	21	24
cestata .....	133	120	90.2	142	114	256	2.13	1.92	..	114	114
All.....	170	150	88.2	182	138	320	2.13	1.88	3	135	138

## VAVII VALLEY.

Collections were secured in this valley during two different seasons, in different years. They were taken from the same part of the small valley and agree in their make-up, though not in the rate of productivity. Taken together, they are remarkable in being composed solely of *cestata* shells, although the distinctness of the markings varies considerably; *apex* like *phæa* is entirely lacking.

The shells fall into three subordinate sections within the *cestata* limits. First and most abundant is the completely and distinctly banded type which has been seen earlier (plate 30, fig. 26). Next there are many which possess the banded spire, but have the bands evanescent on the basal whorl (plate 30, fig. 25). Third, there are some which have markings only on the first and second apical whorls, below which the yellowish-horny ground-color is displayed, with few or many fine striations of a "transverse" nature (plate 30, fig. 24); such shells might readily be mistaken for darker relatives of *apex* or lighter counterparts of *phæa*. The adolescent shells fall into the same groups, although the distinctly banded individuals far outnumber the others, which is only natural in view of the fact that the stripes fade out only on the later-added coils.

Statistically, the Vavii shells are large and somewhat narrowed (table 166). The group of nearly plain shells is shorter than the others, and somewhat stouter, because the width is not greatly diminished. All are devoid of the columellar tooth.

The material of the hot and wet season of 1906 shows a low rate of reproductive activity as compared with that of 1907, taken during the season of less heat and humidity (table 167); the latter compares favorably with the series of Vaiaia and Aiavaro. Obviously the close of the rainy season witnesses a resumption of breeding on the part of a large proportion of the snails.



All of the embryonic young, 141 in number, were banded more or less distinctly but always noticeably. Hence there is further proof that apex and phæa do not exist in this valley.

TABLE 166.—*Partula otaheitana sinistrorsa* (cestata). Vavii Valley.

MEAN VALUE.								
Group.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.	
		mm.	mm.	p. ct.	mm.	mm.	p. ct.	p. ct.
Faint spire bands	19	21.0184 ± .1754	11.3684 ± .0588	54.5526 ± .3495	10.6158 ± .0799	7.9737 ± .0578	75.0790 ± .3596	50.3421 ± .1862
Faint bands....	64	21.5000 ± .0751	11.5125 ± .0477	53.4438 ± .1828	10.6813 ± .0459	7.9437 ± .0388	74.3438 ± .1814	49.6250 ± .1410
Sharp bands....	136	21.4029 ± .0500	11.4044 ± .0302	53.2500 ± .1304	10.6412 ± .0276	7.8574 ± .0225	73.8382 ± .1485	49.7206 ± .0992
All.....	219	21.3979 ± .0428	11.4416 ± .0236	53.4315 ± .1030	10.6507 ± .0229	7.8927 ± .0188	74.0936 ± .1120	49.7466 ± .0762
STANDARD DEVIATION.								
Faint spire bands	19	1.1335 ± .1240	0.3798 ± .0416	2.2589 ± .2471	0.5163 ± .0565	0.3739 ± .0409	2.3241 ± .2543	1.2036 ± .1316
Faint bands....	64	.8908 ± .0531	.5655 ± .0337	2.1679 ± .1292	.5451 ± .0324	.4602 ± .0274	2.1522 ± .1283	1.6724 ± .0997
Sharp bands....	136	.8643 ± .0353	.5219 ± .0213	2.2549 ± .0922	.4778 ± .0195	.3891 ± .0159	2.5673 ± .1050	1.7157 ± .0701
All.....	219	.9391 ± .0302	.5179 ± .0167	2.2593 ± .0728	.5021 ± .0162	.4125 ± .0133	2.4573 ± .0792	1.6726 ± .0539

TABLE 167.—*Partula otaheitana sinistrorsa*. Vavii Valley. Fecundity.

Series.	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.
1906.....	93	59	63.4	55	41	96	1.63	1.03
1907.....	117	98	83.7	150	100	250	2.55	2.14

## VAIPOE VALLEY.

In this small ravine *sinistrorsa* exists in considerable numbers, while *affinis*, as we have seen, is very infrequent. The collections comprise 190 adult and 156 adolescent snails of the former primary variety. The color-form phæa is absent, as in Vavii and Aiavaro. Apex appears, 14 out of 190, but with a modified appearance (plate 30, figs. 27 and 28); the larger whorls are marked transversely with fine and irregularly spaced strigations, so as to resemble lighter cestata individuals with attenuated bands. The shells of the banded color-class cestata fall into the three subordinate groups recognized in Vavii (plate 30, figs. 29 to 35); the specimens figured are somewhat unusual ones, instead of average representatives. Of these three sections, the first comes to resemble the apex color-class, because the bandless whorls display similar strigations; hence it might seem that the shells called apex are really cestata with attenuation of the revolving stripes carried to its extreme. That this supposition is not correct, however, is clear from the comparison of adults and adolescents on the basis of the relative numbers assignable to the several color groups (table 168). Adolescents and adults of the apex class occur in about the same relative numbers, so that this class is sharply distinguished in the early stages. The cestata adolescents show a great preponderance of fully banded individuals, as far as they have formed their shells; obviously the fading of the bands on the last-added whorls can not be noted until these whorls are formed, whereupon



the shell would be taken out of the third subgroup to be placed in one or the other of the contrasted divisions.

The statistical analysis (table 169) shows that the apex class is made up of shells that are longer and narrower than those of *cestata*, but in general there is substantial agreement. As compared with *sinistrorsa* of other localities, this association comprises shells that are by far the largest and best developed in every way. Like the rest of the Taiarapu specimens, they are all toothless.

TABLE 168.—*Partula otaheitana sinistrorsa*. *Vaipoe Valley*. Numerical relations of the color groups.

	Adults.	Adolescents.	Per cent of adults.	Per cent of adolescents.
apex.....	14	13	7.37	8.33
cestata, faintly banded spire, clear basal whorl.....	64	28	33.68	17.95
cestata, faint bands on basal whorl.....	68	35	35.79	22.44
cestata, banded throughout.....	44	80	23.16	51.28
Total.....	190	156	.....	.....

TABLE 169.—*Partula otaheitana sinistrorsa*. *Vaipoe Valley*.

MEAN VALUE.								
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.	
		mm.	mm.	p. ct.	mm.	mm.	p. ct.	p. ct.
apex.....	14	22.1000 ± .1305	11.4429 ± .0908	51.7143 ± .4626	10.8285 ± .1016	7.9714 ± .0618	73.3572 ± .5654	49.0000 ± .4186
cestata ..	176	21.7881 ± .0510	11.4568 ± .0251	52.4659 ± .1090	10.7863 ± .0288	7.8853 ± .0212	73.0228 ± .1263	49.4319 ± .0871
All.....	190	21.8111 ± .0483	11.4558 ± .0242	52.4106 ± .1070	10.7894 ± .0276	7.8915 ± .0207	73.0474 ± .1242	49.4000 ± .0867
STANDARD DEVIATION.								
apex.....	14	0.7238 ± .0923	0.5038 ± .0642	2.5665 ± .3271	0.5637 ± .0718	0.3432 ± .0437	3.1363 ± .3998	2.3222 ± .2960
cestata ..	176	1.0026 ± .0360	.4944 ± .0177	2.1450 ± .0771	.5663 ± .0203	.4183 ± .0150	2.4839 ± .0893	1.7131 ± .0616
All.....	190	.9872 ± .0341	.4952 ± .0171	2.1879 ± .0756	.5644 ± .0195	.4240 ± .0146	2.5392 ± .0878	1.7727 ± .0613

The data on fecundity may be given without tabulation. Of 140 adults yielding records, 104 were gravid (74.3 per cent); they contained 146 eggs and 94 young, a total of 240, giving an average content for the gravid individuals of 2.3 and an average for all of 1.7. Passing to the inheritance of the distinctive color-characters, it appears (table 170) that apex produces both its own kind and cestata as well, but that cestata adults bear only banded young; this result is much like that observed in Aiavaro. The small relative number of unbanded adults renders it impossible to interpret the facts as indicating a secular change in the colony.

TABLE 170.—*Partula otaheitana sinistrorsa*. *Vaipoe Valley*. Heredity.

	Young, apex.	Young, cestata.	Total.
Adults:			
apex.....	3	3	6
cestata.....	..	88	88
Total.....	3	91	94

## THE COLONIES OF TAHITI NUI—APIRIMAUE TO TAHARUA VALLEYS.

Passing westward from the last Taiarapu colony, we must return to the major land-mass of Tahiti. It has been stated earlier that Haoma Valley in the peninsula is not inhabited by *sinistrorsa*, as far as the collection may be taken to represent the actual population; if it occurs at all, its numbers must be very few. Likewise Oopu Valley, which is the easternmost valley of the southern tier in Tahiti nui, seems to have no *sinistrorsa* inhabitants, although *rubescens* flourishes here as nowhere else in the island. The total range of *sinistrorsa* is thus interrupted by a lacuna extending from Vaipoe to Apirimaue.

The region from Apirimaue westward is a subsidiary area which comprises the original range of the primary variety, as Garrett has stated in the most explicit terms. From this, *sinistrorsa* has passed to occupy the four valleys of Taiarapu, and from it also emigrants seem to have passed in small numbers to the eastern quadrant; a single immature snail found in Faone Valley is the positive observation upon which this statement is based.

The colonies of this area are extremely complex and they are much differentiated *inter se*. Whether or not their diversity is recent in origin, the fact remains that for the time of investigation *sinistrorsa* does not "present the same features through all the valleys for a distance of 10 or 12 miles." Nor is it by any means always sinistral; dextral members actually outnumber the typical reversed snails in at least one valley, while at other points sporadic or abundant dextral mutants make their appearance. Dimensional differences that must have escaped the notice of Garrett are brought to light by the statistical treatment of the measurements of the shells. Such being the case, it is possible to conduct a profitable analysis of the *sinistrorsa* material from this region, always with a view to the general problem as to the relative values of congenital and environmental factors of racial differentiation.

## APIRIMAUE VALLEY.

The members of this association are all sinistral, and fall into the three color-classes distinguished in Vaiaaia. The type apex is represented by 16 snails (5.6 per cent), phæa by only 4 (1.4 per cent), while 264 distinctly banded *cestata* make up the bulk of the colony. It was here, the last valley of the range of *affinis*, that Garrett stated he "took a few examples of *sinistrorsa*"; now this primary variety exists in abundance.

In statistical respects (table 171) the phæa class departs greatly from the *cestata* class in absolute measures, being smaller in all cases. On casual acquaintance, the observer might suppose that they were sinistral relatives of the few dextral *affinis* that exist here, on account of the similarity in coloring; but their form is characteristic, while furthermore the offspring of the *affinis* are always dextral. Other considerations are adduced below, enforcing the conclusion that the so-called phæa snails are true constituents of the *sinistrorsa* association, in this valley as in Vaiaaia and elsewhere. The other details of the statistical table need no verbal explanation. All shells are toothless, as in Taiarapu.

In fertility at the time of collection (the drier season of 1907) an average degree is indicated (table 172) except for the *phæa* class, which falls below the others; the numbers are too few, however, to give a basis for a definite statement as to the existence of differential fertility.

The data of heredity (table 172) are particularly interesting in view of what was discovered further west. Apex adults produce young of all three kinds, with their own type in greater abundance. The same may be said of the *cestata* class. But the single embryonic shell taken from a *phæa* adult was an unmistakable apex. The total number of *phæa* among the young is greater than in the series of gravid adults; this may point to a secular change in the color-complexion of the colony as a whole, or it may be something that would disappear if more observations were at hand. In any case the genetic interrelationships of apex, *cestata*, and *phæa* are manifest.

TABLE 171.—*Partula otaheitana sinistrorsa*. *Apirimaue Valley*.

MEAN VALUE.								
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.	
		<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>p. ct.</i>
apex . . . .	16	19.5000 ± .1214	10.8125 ± .0942	55.3750 ± .2139	9.8000 ± .1309	7.2250 ± .0799	73.8750 ± .4577	50.2500 ± .3010
cestata . .	264	19.3988 ± .0407	10.6939 ± .0208	55.0606 ± .1009	9.5983 ± .0202	7.1810 ± .0155	74.8637 ± .1106	49.3334 ± .0763
phæa . . . .	4	18.6500 ± .1430	10.5500 ± .0292	56.7500 ± .6021	9.4500 ± .0735	7.0000 ± .1012	74.0000 ± 1.2952	50.5000 ± .0
All . . . .	284	19.3926 ± .0371	10.6993 ± .0200	55.1021 ± .0953	9.6042 ± .0198	7.1810 ± .0152	74.7958 ± .1080	59.4014 ± .0737
STANDARD DEVIATION.								
apex . . . .	16	0.7202 ± .0858	0.5588 ± .0666	1.2686 ± .1512	0.7762 ± .0933	0.4737 ± .0565	2.7146 ± .3236	1.7853 ± .2128
cestata . .	264	.9765 ± .0288	.5003 ± .0147	2.4301 ± .0713	.4862 ± .0143	.3745 ± .0109	2.6638 ± .0782	1.8388 ± .0539
phæa . . . .	4	.4242 ± .1011	.0866 ± .0206	1.7853 ± .4257	.2179 ± .0520	.3000 ± .0715	3.8406 ± .9158	0
All . . . .	284	.9265 ± .0262	.5008 ± .0141	2.3812 ± .0674	.4949 ± .0140	.3806 ± .0107	2.6979 ± .0764	1.8397 ± .0521

TABLE 172.—*Partula otaheitana sinistrorsa*. *Apirimaue Valley*.

FECUNDITY.									HEREDITY.			
Series	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.	Young apex.	Young cestata.	Young phæa.	Total.
apex . . . . .	16	13	81.2	16	11	27	2.07	1.69	7	1	3	11
cestata . . . .	247	217	87.8	288	157	445	2.05	1.80	4	151	2	157
phæa . . . . .	4	3	75.0	3	1	4	1.33	1.00	1	...	..	1
All . . . . .	267	233	87.3	307	169	476	2.04	1.78	12	152	5	169

## TITAVIRI VALLEY.

With this valley we enter a region where dextral representatives of *sinistrorsa* appear in substantial numbers; here they amount to about one-third of the whole *otaheitana* collection.

The reversed shells fall into the three established color-classes (plate 30, figs. 36 to 38, 40 to 44, and 46), of which both apex and *phæa* are more numerously

represented than in *Apirimaue*. The dextral adults belong to *cestata* (plate 30, fig. 45) and *phæa* (plate 30, figs. 47 to 49), but in addition one immature specimen of the apex type was found (plate 30, fig. 39).

The statistical data (table 173) bring out very marked differences between the sinistral and dextral divisions, and between color-classes of the same mode of coil. As regards the first point, it appears that in all of the eight characters the differences are beyond the scope of probable error. In the second connection, it is interesting to find that sinistral apex are larger and somewhat narrower than *cestata* of the same coil, for in other valleys they have not differed in both of those ways. *Phæa* of the reversed coil is much like *cestata*. All of the sinistral groups exhibit little or nothing in the way of a columella tooth.

TABLE 173.—*Partula otaheitana sinistrorsa*. Titaviri Valley.

MEAN VALUE.									
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index. <sup>1</sup>
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
apex, sin. . . . .	25	mm. 20.1260 ± .1219	mm. 11.0760 ± .0583	p. ct. 54.9000 ± .2804	mm. 10.2040 ± .0656	mm. 7.6440 ± .0542	p. ct. 74.8200 ± .3694	p. ct. 50.7000 ± .2473	1.0000 ± .0
cestata, sin. . . .	115	19.6908 ± .0428	10.8530 ± .0329	55.0452 ± .1694	10.1156 ± .0302	7.5678 ± .0254	74.8739 ± .1976	51.3434 ± .1166	1.0435 ± .0183
phæa, sin. . . . .	25	19.6460 ± .1504	10.9880 ± .0571	55.9000 ± .4333	10.1000 ± .0586	7.5160 ± .0586	74.3000 ± .4364	51.4600 ± .2684	1.3462 ± .0894
All, sin. . . . .	165	19.7500 ± .0483	10.9073 ± .0264	55.1697 ± .1426	10.1267 ± .0249	7.5715 ± .0215	74.7788 ± .1629	51.2636 ± .0991	1.0774 ± .0188
cestata, dex. . . .	15	18.4300 ± .1433	10.5266 ± .0659	57.0333 ± .3701	9.7133 ± .0601	7.1933 ± .0461	73.7000 ± .3377	52.8333 ± .3027	2.2000 ± .2479
phæa, dex. . . . .	62	18.0403 ± .0669	10.3705 ± .0303	57.3871 ± .1801	9.5645 ± .0421	7.0226 ± .0281	73.2903 ± .2182	52.7903 ± .1763	3.1935 ± .1108
All, dex. . . . .	77	18.1162 ± .0618	10.4013 ± .0280	57.3182 ± .1334	9.5935 ± .0514	7.0558 ± .0248	73.3701 ± .1880	52.7987 ± .1537	3.0000 ± .1058
STANDARD DEVIATION.									
apex, sin. . . . .	25	0.9035 ± .0862	0.4320 ± .0412	2.0784 ± .1983	0.4870 ± .0464	0.4021 ± .0383	2.7381 ± .2612	1.8330 ± .1749	0
cestata, sin. . . .	115	.6815 ± .0303	.5231 ± .0233	2.6934 ± .1198	.4808 ± .0213	.4042 ± .0179	3.1414 ± .1397	1.8537 ± .0824	.2918 ± .0129
phæa, sin. . . . .	25	1.1151 ± .1063	.4236 ± .0404	3.2124 ± .3064	.4345 ± .0414	.4342 ± .0414	3.2249 ± .3086	1.9895 ± .1898	.6762 ± .0632
All, sin. . . . .	165	.9191 ± .0341	.5034 ± .0187	2.7158 ± .1008	.4750 ± .0176	.4101 ± .0152	3.1034 ± .1152	1.8872 ± .0701	.3619 ± .0133
cestata, dex. . . .	15	.8231 ± .1013	.3785 ± .0466	2.1250 ± .2617	.3452 ± .0425	.2619 ± .0326	1.9391 ± .2388	1.7384 ± .2140	1.4236 ± .1753
phæa, dex. . . . .	62	.7807 ± .0473	.3540 ± .0214	2.1031 ± .1273	.4922 ± .0298	.3279 ± .0199	2.5472 ± .1543	2.0587 ± .1246	1.2931 ± .0783
All, dex. . . . .	77	.8041 ± .0437	.3641 ± .0198	1.7358 ± .0943	.4688 ± .0363	.3233 ± .0175	2.4460 ± .1329	2.0004 ± .1087	1.3769 ± .0748

<sup>1</sup>The numbers in the sinistral groups are 27, 115, 26; 168.

Among the dextral shells, where apex does not appear, *cestata* and *phæa* are alike in being far shorter and relatively stouter than their sinistral counterparts, while the tooth attains a remarkable degree of development. The second class resembles *affinis* so greatly that its parallel origin seems almost impossible; yet the data on heredity are such as to prove the *sinistrosa* nature of all of the dextral individuals in this valley.

The number of embryonic young is small (table 174) on account of the relatively large number of eggs as compared with unborn snails of fuller growth; the material was secured in the wet season of 1906, when reproductive activity had only recently been resumed. Classification of such young as were found could not be made parallel to that of the adults, because the colors of the embryonic shells were very

faint. In no case, however, did banded young appear (table 175); all were plain, and either light horny-brown or dark brown in color. Whether or not these two divisions correspond with apex and phæa can not be determined. Either the preservative had affected the colors and patterns in the case of this collection, or else the distinctive color-class characters are not developed until post-embryonic life. From the facts as observed in contiguous valleys, the latter is indicated as the correct interpretation, which agrees, furthermore, with the results in the case of the Vaipoe association.

TABLE 174.—*Partula otaheitana sinistrorsa*. Titaviri Valley. Fecundity.

Series.	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.
apex, sinistral.....	22	17	77.2	21	14	35	2.05	1.59
cestata, sinistral.....	106	83	78.3	84	47	131	1.57	1.23
phæa, sinistral.....	20	18	90.0	16	21	37	2.05	1.85
All, sinistral.....	148	118	79.7	121	82	203	1.72	1.37
cestata, dextral.....	14	12	85.7	14	2	16	1.33	1.14
phæa, dextral.....	54	38	70.3	32	23	55	1.44	1.01
All, dextral.....	68	50	73.5	46	25	71	1.42	1.04

In the case of the heredity of the coil, there can be no question as to the correctness of the observations. Table 175 and its summary give the proof that in a few instances at least an adult of one kind may bear young of the contrasted form of spiral. If two or more young are present in the brood pouch they are of the same mode, *whether or not this agrees with the parental direction of spirality*. The total numbers of reversed and direct young agree closely with those for gravid parents.

TABLE 175.—*Partula otaheitana sinistrorsa*. Heredity. Titaviri Valley.

FULL STATISTICS.						SUMMARY.			
	Young, sinistral.		Young, dextral.		Total.		Young, sinistral.	Young, dextral.	Total.
	Light brown, plain.	Dark brown, plain.	Light brown, plain.	Dark brown plain.					
Adults:						Adults:			
apex, sinistral.....	11	3	....	....	14	Sinistral....	78	4	82
cestata, sinistral....	9	37	1	....	47	Dextral....	1	24	25
phæa, sinistral.....	6	12	1	2	21	Total....	79	28	107
cestata, dextral....	1	....	....	1	2				
phæa, dextral.....	....	....	11	12	23				
Total.....	27	52	13	15	107				

## TENAIRE VALLEY.

Among the colonies of true *sinistrorsa* that of Tenaire Valley is in many ways the most interesting and valuable. While it is exceedingly complex, there is an abundance of material in hand for its analysis; 555 adults and 79 adolescents were taken in 1907, and in 1909 a series of 352 full-grown and 69 immature snails was secured. In the latter year more attention was paid to other species of the genus,

wherefore the collection of *sinistrorsa* was intentionally smaller. The area of collection was the same for both years. The gravid adults yielded 685 young snails to be used for the study of heredity; in sum, therefore, more than 1,700 *sinistrorsa* of all ages were obtained in Tenaire.

The make-up of the adult material of the collection is given in table 176. The notable features are (1) the abundance and clear preponderance of dextral snails; (2) the lesser numbers of *cestata* as compared with *apex* in the sinistral division and with *phæa* in the dextral group; (3) the extraordinary abundance of *phæa*, which amounts to 67 per cent of the dextral series and only a little less than half of all.

TABLE 176.—*Partula otaheitana sinistrorsa*. Tenaire Valley. Numerical relations.

Color-class.	Sinistral.			Dextral.		
	No. of adults.	Per cent of sin. series.	Per cent. of all	No. of adults.	Per cent of dex. series.	Per cent of all.
<i>apex</i> .....	193	51.6	21.2	51	9.6	5.6
<i>cestata</i> .....	109	29.2	13.1	124	23.2	13.7
<i>phæa</i> .....	72	19.2	7.9	358	67.2	39.5
Total .....	374	100.0	41.2	533	100.0	58.8

Variation within the limitations of the color-class is unusually wide; *apex* is much as before (plate 31, figs. 1 and 2, 11 to 13), but *cestata* and *phæa* present new features in addition to their qualities as seen in Titaviri and earlier. Aside from peculiarities in form and size, the *cestata* shells vary considerably (plate 31, figs. 3 to 7); some exhibit a terminal merging of the subsutural and median zones (fig. 3), and they grade through the typical patterns to narrow-striped shells like that shown in figure 6, plate 31. Constriction of the median girdle gives a type with a zone of intermediate width (plate 31, fig. 7). All of these subordinate modifications are displayed by dextral *cestata* as well, some of which are shown in figures 14 to 16, plate 31. The color-group called *phæa* (plate 31, figs. 8 to 10, 17 to 19) includes shells with a modified coloration, and one which agrees with that specified as *confluens* (*confluens*) by Pilsbry (figs. 8, 10, and 17). Usually they are typically uniform in color, sometimes of a very deep nature (fig. 18); the shell figured as No. 16 is a dwarfed mutant, which, in spite of its diminutive size, was that of a gravid adult. The embryonic shells (plate 31, fig. 20, A to F) display the adult types of coloration in both coils.

A rigid and thorough-going analysis on the basis of the statistical data (table 177) would involve (1) the comparison *inter se* of the three main color-classes in each mode of coil; (2) the comparison of sinistral and dextral groups of one and the same class; (3) the examination of the general relations of all sinistral to all dextral shells. A verbal transcript of the facts is unnecessary, for these are evident from inspection of the table. The noteworthy points are (1) the remarkably close agreement of the three dextral classes, both in dimensions and proportions; (2) the smaller size of the directly coiled shells as compared with the reversed ones, although

the proportions are not essentially diverse; (3) the greater development of the tooth in the dextral division, precisely as in Titaviri; (4) the consistent absence of the tooth in sinistral apex, again as in Titaviri and Apirimaue; (5) the smaller size of the phæa class of both modes of coil.

TABLE 177.—*Partula otaheitana sinistrorsa*. *Tenaire Valley*.

MEAN VALUE.									
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index. <sup>1</sup>
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
		<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>p. ct.</i>	
apex, sin. . .	188	19.2149 ± .0390	10.6829 ± .0218	55.5053 ± .1078	9.8329 ± .0235	7.4510 ± .0180	75.6383 ± .1257	51.2606 ± .0905	1
cestata, sin. .	106	19.0575 ± .0676	10.6887 ± .0320	56.0943 ± .1801	9.8509 ± .0335	7.4849 ± .0264	76.1226 ± .1818	51.5943 ± .1441	1.0734 ± .0191
phæa, sin. . .	70	18.8728 ± .0938	10.6657 ± .0396	56.3571 ± .2103	9.7600 ± .0440	7.4343 ± .0310	76.2428 ± .2060	51.5571 ± .1341	1.0435 ± .0165
All, sin. . . .	364	19.1033 ± .0338	10.6813 ± .0162	55.8406 ± .0874	9.8242 ± .0180	7.4522 ± .0136	75.8956 ± .0932	51.3599 ± .0688	1.0296 ± .0065
apex, dex. . .	48	17.9313 ± .0907	10.1292 ± .0386	56.5208 ± .2172	9.2542 ± .0384	6.9334 ± .0204	75.0834 ± .1945	51.6041 ± .1723	1.8776 ± .1042
cestata, dex. .	120	17.9550 ± .0511	10.0950 ± .0249	56.1166 ± .1438	9.2200 ± .0278	6.9384 ± .0205	75.1750 ± .1452	51.2750 ± .1201	2.0496 ± .0663
phæa, dex. . .	355	17.9520 ± .0297	10.0927 ± .0147	56.1648 ± .0815	9.2488 ± .0164	6.9530 ± .0129	75.1028 ± .1000	51.4295 ± .0668	2.2950 ± .0393
All, dex. . . .	523	17.9508 ± .0248	10.0965 ± .0120	56.1864 ± .0676	9.2426 ± .0133	6.9478 ± .0104	75.1176 ± .0777	51.4101 ± .0554	2.1806 ± .0320
STANDARD DEVIATION.									
apex, sin. . .	188	0.7928 ± .0276	0.4436 ± .0154	2.1916 ± .0752	0.4785 ± .0166	0.3664 ± .0127	2.5561 ± .0879	1.8401 ± .0630	0.0
cestata, sin. .	106	1.0327 ± .0478	.4882 ± .0226	2.7498 ± .1273	.5116 ± .0237	.4025 ± .0187	2.7761 ± .1285	2.2000 ± .1019	.2938 ± .0134
phæa, sin. . .	70	1.1638 ± .0663	.4792 ± .0280	2.6092 ± .1477	.5465 ± .0311	.3850 ± .0219	2.5561 ± .1456	1.6638 ± .0948	.2039 ± .0117
All, sin. . . .	364	.9555 ± .0239	.4580 ± .0114	2.4738 ± .0618	.5083 ± .0127	.3863 ± .0096	2.6359 ± .0659	1.9471 ± .0486	.1848 ± .0046
apex, dex. . .	48	.9322 ± .0641	.3968 ± .0263	2.2313 ± .1536	.3950 ± .0261	.2098 ± .0144	1.9983 ± .1375	1.7706 ± .1208	1.0811 ± .0737
cestata, dex. .	120	.8306 ± .0351	.4053 ± .0166	2.3352 ± .1007	.4512 ± .0196	.3329 ± .0145	2.3591 ± .1027	1.9513 ± .0839	1.0821 ± .0469
phæa, dex. . .	355	.8310 ± .0210	.4114 ± .0094	2.2773 ± .0576	.4587 ± .0116	.3620 ± .0091	2.7938 ± .0707	1.8669 ± .0472	1.0991 ± .0278
All, dex. . . .	523	.8408 ± .0175	.4085 ± .0085	2.2942 ± .0478	.4518 ± .0094	.3551 ± .0073	2.6351 ± .0549	1.8801 ± .0392	1.0890 ± .0226

<sup>1</sup>The numbers are: Sinistral, 193, 109, 69; 371; dextral, 49, 121, 356; 526.

The statistics relating to fecundity (table 178) combine the observations for the two years, because the material was collected during the same month of the year. A direct examination of the question proves that the relations are almost exactly the same in the two series. No real degree of differential fertility comes to light, although the dextral adults bear fewer young on the average and the several classes differ somewhat among themselves.

In dealing with the facts of inheritance there is no difficulty where the direction of spirality is concerned, but in the case of the differential characters of the color-classes insuperable obstacles are encountered. The figures are given in full and in summary in table 179. It is remarkable that the total numbers of sinistral and dextral young agree almost exactly with the figures for the gravid adults. As the latter form about 90 per cent of the whole representative population, in both modes of coil, this agreement indicates a stable condition of the colony as regards the proportionate numbers of reversed and directly coiled snails.

The inheritance of the color-characters can not be dealt with so confidently, for the reason that *unbanded* young range from typical *apex* to undoubted *phæa* with all gradations between these extremes. The illustrations already specified show the typical forms. The bands of *cestata* individuals appear plainly at a very early age, but the differentiation of unbanded young into *apex* and *phæa* occurs much later

TABLE 178.—*Partula otaheitana sinistrorsa*. *Tenaire Valley*. *Fecundity*.

	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.
apex, sinistral. . . . .	193	176	91.2	250	140	390	2.22	2.02
cestata, sinistral. . . . .	109	98	89.9	151	83	232	2.37	2.13
phæa, sinistral. . . . .	72	66	91.7	99	49	148	2.24	2.05
All, sinistral. . . . .	374	340	90.9	500	272	772	2.27	2.06
apex, dextral. . . . .	50	44	88.0	56	39	95	2.16	1.90
cestata, dextral. . . . .	110	102	92.7	131	96	227	2.22	2.06
phæa, dextral. . . . .	347	316	91.1	398	278	676	2.14	1.95
All, dextral. . . . .	507	462	91.1	585	413	998	2.16	1.97

TABLE 179.—*Partula otaheitana sinistrorsa*. *Tenaire Valley*.

FULL STATISTICS OF HEREDITY.						
		Young, sinistral.		Young, dextral.		Total
		Plain.	Banded.	Plain.	Banded.	
Adults:						
apex, sinistral.....		126	14	...	..	140
cestata, sinistral.....		28	53	...	2	83
phæa, sinistral.....		32	11	4	2	49
apex, dextral.....		3	..	32	4	39
cestata, dextral.....		2	1	45	48	96
phæa, dextral.....		4	..	257	17	278
Total.....		195	79	338	73	685

SUMMARY. HEREDITY OF COIL.				SUMMARY. HEREDITY OF COLOR-PATTERN.			
	Young, sinistral.	Young, dextral.	Total.		Young, plain.	Young, cestata.	Total.
Adults:				Plain{apex..... phæa..... cestata.....}			
Sinistral....	264	8	272		458	48	506
Dextral....	10	403	413		75	104	179
Total....	274	411	685	Total.....	533	152	685

in the majority of instances. If we combine *apex* and *cestata* so as to have "plain" and "banded" divisions in parental and offspring generations, then the figures indicate (1) that heredity of color-pattern is regular, and possibly proceeds according to Mendelian principles, provided that the banded character appears a little later in some individuals, or (2) that the smaller relative numbers of *cestata* among the embryonic snails indicates a colonial change. In my opinion, the former alternative is preferable, especially in view of the facts observed in *Titaviri*.



## MAARA VALLEY.

The general composition of the *sinistrorsa* colony from Maara is like that of Tenaire, inasmuch as all three color-classes are represented in each mode of coil. Here, however, the *cestata* group is the largest. The shells are so typical as to render their illustration unnecessary.

On statistical examination (table 180) the sinistral *cestata* and *phæa* groups prove to be *shorter* and *stouter* than their dextral correspondents—relations which are the exact opposites of what was found in Tenaire. The reversed group as a whole is consistently stouter than the dextral division, although in some cases, such as the proportions of the aperture, the figures are similar.

TABLE 180.—*Partula otaheitana sinistrorsa*. Maara Valley.

MEAN VALUE.									
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
		<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>p. ct.</i>	
apex, sin. ....	7	17.5786 ± .1146	10.3000 ± .0982	58.5000 ± .5098	8.9000 ± .1020	7.0429 ± .1080	78.6428 ± .8111	50.6428 ± .3712	1.1428 ± .0892
cestata, sin. ...	76	18.0461 ± .0651	10.2921 ± .0327	56.9210 ± .1789	9.1158 ± .0384	7.0474 ± .0270	77.3684 ± .2319	50.6052 ± .1600	1.0658 ± .0192
phæa, sin. ....	49	17.9602 ± .0720	10.3367 ± .0478	57.2347 ± .2301	9.1735 ± .0443	7.1163 ± .0360	77.4592 ± .2571	50.8877 ± .1638	1.1600 ± .0398
All, sin. ....	132	18.0045 ± .0473	10.3091 ± .0264	57.1212 ± .1381	9.1276 ± .0284	7.0727 ± .0214	77.4697 ± .1704	50.7121 ± .1124	1.1052 ± .0193
apex, dex. ....	4	18.1375 ± .2723	9.9000 ± .0477	54.7500 ± .9868	8.9500 ± .0559	7.0000 ± .1216	77.6250 ± 1.3630	51.0000 ± .7727	1.0000 ± .0
cestata, dex. ...	36	18.0167 ± .0909	9.9112 ± .0299	55.0278 ± .2874	9.0889 ± .0468	6.9167 ± .0376	75.8055 ± .3076	50.5000 ± .2385	1.1666 ± .0265
phæa, dex. ....	29	18.1638 ± .1064	10.0035 ± .0601	55.0173 ± .2803	9.1690 ± .0618	6.9207 ± .0457	75.3621 ± .3628	50.4655 ± .2547	1.1724 ± .0473
All, dex. ....	69	18.0848 ± .0673	9.9493 ± .0353	54.9203 ± .1986	9.1145 ± .0361	6.9232 ± .0284	75.7319 ± .2387	50.5145 ± .1701	1.1571 ± .0293
STANDARD DEVIATION.									
apex, sin. ....	7	0.4495 ± .0810	0.3854 ± .0684	2.0000 ± .3605	0.4000 ± .0711	0.4238 ± .0754	3.1816 ± .5735	1.4562 ± .2625	0.3499 ± .0621
cestata, sin. ...	76	.8419 ± .0460	.4223 ± .0231	2.3128 ± .1265	.4971 ± .0261	.3491 ± .0181	2.9971 ± .1640	2.0684 ± .1131	.2479 ± .0126
phæa, sin. ....	49	.7475 ± .0499	.4959 ± .0338	2.3885 ± .1627	.4601 ± .0313	.3743 ± .0244	2.6683 ± .1818	1.7001 ± .1158	.4176 ± .0271
All, sin. ....	132	.8052 ± .0334	.4498 ± .0187	2.3533 ± .0976	.4833 ± .0201	.3649 ± .0151	2.9023 ± .1205	1.9149 ± .0795	.3305 ± .0126
apex, dex. ....	4	.8076 ± .1925	.1414 ± .0337	2.9262 ± .6968	.1658 ± .0395	.3605 ± .0860	4.0415 ± .9638	2.2913 ± .5454	.0
cestata, dex. ...	36	.8092 ± .0633	.2665 ± .0211	2.5569 ± .2032	.4162 ± .0331	.3346 ± .0266	2.7368 ± .2175	2.1213 ± .1676	.2357 ± .0177
phæa, dex. ....	29	.8500 ± .0752	.4804 ± .0425	2.2379 ± .1982	.4935 ± .0437	.3652 ± .0323	2.8971 ± .2565	2.0339 ± .1801	.3778 ± .0334
All, dex. ....	69	.8291 ± .0476	.4352 ± .0249	2.4459 ± .1404	.4443 ± .0255	.3498 ± .0201	2.9397 ± .1688	2.0955 ± .1203	.3639 ± .0197

Considerable variation in fecundity is displayed (table 181), but it remains an open question whether differential fertility actually exists.

As before, the data of heredity must be treated with reserve in the case of color; the direction of coil is something that can be determined with certainty. In presenting the facts (table 182) we may include a number of very small snails ("egg-young") which were sufficiently advanced to display their direction of spirality but not their definitive colors. A slight excess of the dextral type appears in the embryonic population (table 182). Combining the groups of apex and phæa adults a slight decrease of *cestata* among the young is observed, but this is probably due to a later appearance of the bands in certain cases.

TABLE 181.—*Partula otaheitana sinistrorsa*. Maara Valley. Fecundity.

Series.	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.
apex, sinistral.....	7	6	85.7	6	5	11	1.83	1.57
cestata, sinistral.....	76	71	93.4	104	63	167	2.35	2.20
phæa, sinistral.....	50	44	88.0	60	33	93	2.11	1.86
All, sinistral.....	133	121	91.0	170	101	272	2.25	2.04
apex, dextral.....	5	3	60.0	2	6	8	2.67	1.60
cestata, dextral.....	36	34	94.4	40	34	74	2.17	2.05
phæa, dextral.....	29	25	86.2	29	22	51	2.04	1.76
All, dextral.....	70	62	88.5	71	62	133	2.14	1.90

TABLE 182.—*Partula otaheitana sinistrorsa*. Maara Valley.

FULL STATISTICS OF HEREDITY.							
	Young, sinistral.			Young, dextral.			Total.
	Plain.	Banded.	Egg-young.	Plain.	Banded.	Egg-young.	
apex, sinistral.....	3	..	....	1	..	(1)	4 (5)
phæa, sinistral.....	14	3	(4)	9	..	(3)	26 (33)
cestata, sinistral.....	9	32	(14)	1	5	(2)	47 (63)
apex, dextral.....	3	..	(3)	..	..	....	3 (6)
phæa, dextral.....	11	1	(2)	4	..	(4)	16 (22)
cestata, dextral.....	1	7	(4)	3	14	(5)	25 (34)
Total.....	41	43	(27)	18	19	(15)	121 (163)

SUMMARY. HEREDITY OF COIL.				SUMMARY. HEREDITY OF COLOR-PATTERN.			
	Young, sinistral.	Young, dextral.	Total.		Young, plain.	Young, cestata.	Total.
Adults:				Adults:			
Sinistral.....	79	22	101	Plain {apex.....	45	4	49
Dextral.....	17	47	62	{phæa.....	14	58	72
				{cestata....			
Total.....	96	69	163	Total.....	59	62	121

## VAIHIRIA AND VAIRAHARAH VALLEYS.

The topographical relations of these two valleys have been explained at an earlier point in the discussion of *Partula clara*, but certain features need to be recalled. In effect, Vaihira and Vairaharaha are sister parts of one great valley, which is divided by a long mountain spur down its center. The outward portions of the two are confluent some little distance before the coastal plain is reached. Each element, however, has a long and straight course and is independent of the other throughout most of its length. So far as *P. clara* is concerned, as we have seen, the two colonies are really separate. The same is true for *P. otaheitana sinistrorsa*, for snails are not taken coastward of the dividing ridge; yet the *sinistrorsa* associations are very similar in most respects and are dually different from the Maara and eastward series. For the sake of condensation, they will be considered together.

All of the material is sinistral; apex is absent, so that only two color-types occur in each valley. Of these, *cestata* in *Vaihiria* is 10 times as abundant as the other (91.4 per cent of all), while in *Vairaharaha* it forms only 21.0 per cent of the whole association. The *Vaihiria* shells of this class (plate 31, figs. 25 to 28) grade from very dark examples, with considerable cross-suffusion of the bands (fig. 28), to almost clear yellow shells with only the faintest indication of the encircling girdle (fig. 25).

The other color-class (plate 31, figs. 21 to 24) agrees in part with *phæa* of earlier valleys, in so far as dark-brown shells with stained lips occur (fig. 22). Less intense solid browns are shown by the majority of the shells (fig. 21), but still others are present which are new in the details of their coloration (figs. 23, 24). They display

TABLE 183.—*Partula otaheitana sinistrorsa*. *Vaihiria* and *Vairaharaha* Valleys.

MEAN VALUE.								
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.	
<i>Vaihiria</i> , <i>cestata</i> .... <i>phæa</i> .....	277	<i>mm.</i> 18.2687 ± .0317	<i>mm.</i> 10.2329 ± .0157	<i>p. ct.</i> 55.9621 ± .0902	<i>mm.</i> 9.2394 ± .0162	<i>mm.</i> 7.0834 ± .0123	<i>p. ct.</i> 76.5541 ± .1001	<i>p. ct.</i> 50.5000 ± .0709
	26	18.3269 ± .0907	10.2154 ± .0632	55.7692 ± .2685	9.2462 ± .0585	7.1384 ± .0488	76.8461 ± .3740	50.4231 ± .1868
<i>Vaihiria</i> , all.....	303	18.2738 ± .0300	10.2314 ± .0154	55.9455 ± .0813	9.2399 ± .0157	7.0881 ± .0120	76.5792 ± .0970	50.4934 ± .0668
<i>Vairaharaha</i> , <i>cestata</i> .... <i>phæa</i> ..	52	18.0443 ± .0779	10.1385 ± .0378	56.1154 ± .1900	9.2462 ± .0418	7.0962 ± .0316	76.3846 ± .1998	51.2884 ± .1494
	195	18.1085 ± .0356	10.1154 ± .0197	55.8282 ± .1020	9.2559 ± .0214	7.0385 ± .0154	75.8743 ± .1262	51.0282 ± .0822
<i>Vairaharaha</i> , all....	247	18.0949 ± .0325	10.1202 ± .0174	55.8887 ± .0900	9.2539 ± .0191	7.0506 ± .0139	75.9818 ± .1085	51.0830 ± .0741
STANDARD DEVIATION.								
<i>Vaihiria</i> , <i>cestata</i> .... <i>phæa</i> .....	277	0.7821 ± .0224	0.3886 ± .0110	2.2262 ± .0638	0.4009 ± .0114	0.3047 ± .0087	2.4702 ± .0708	1.7497 ± .0501
	26	.6857 ± .0641	.4777 ± .0447	2.0297 ± .1898	.4422 ± .0414	.3680 ± .0345	2.8277 ± .2644	1.4121 ± .1321
<i>Vaihiria</i> , all.....	303	.7745 ± .0212	.3970 ± .0109	2.0975 ± .0575	.4044 ± .0111	.3110 ± .0085	2.5041 ± .0686	1.7243 ± .0472
<i>Vairaharaha</i> , <i>cestata</i> .... <i>phæa</i> ..	52	.8331 ± .0551	.4039 ± .0267	2.0309 ± .1343	.4474 ± .0295	.3385 ± .0223	2.1362 ± .1413	1.5977 ± .1056
	195	.7382 ± .0252	.4075 ± .0139	2.1110 ± .0721	.4441 ± .0151	.3182 ± .0109	2.6132 ± .0892	1.7016 ± .0581
<i>Vairaharaha</i> , all....	247	.7585 ± .0230	.4069 ± .0123	2.0977 ± .0636	.4448 ± .0135	.3234 ± .0098	2.5289 ± .0767	1.7262 ± .0524

transverse strigations of medium brown upon a yellowish-brown background; these strigations are not as ill-defined as in the color-form noted earlier, which corresponds with the *confluens* of Pilsbry, nor is the ground-color so dark. For purposes of description, this subordinate color-form of the *phæa* class will be called *striata*. Apparently, then, the unbanded class equivalent to *phæa* of the neighboring eastern valleys has become more complex, although its variation is still continuous and has not led to its differentiation into distinct subgroups. In *Vairaharaha* very few of the strigated shells occur, and therefore the group corresponds more nearly with *phæa* of *Maara*.

In statistical respects (table 183) the two classes of each valley agree closely with one another. The two colonies differ in several characters, and in some instances the divergence is significant. One point of general agreement is found in the absolute lack of a columellar tooth, even as a trace; this is very important, for

the colonies on both sides of this double valley have a positive development of this feature.

The *Vaihiria* series was taken in March (1906) and that of *Vairaharaha* in June (1907), hence in different seasons. As would be expected, fecundity is relatively and absolutely lower in the former series (table 184).

The data of heredity (table 184) are such as to signify a late development of the revolving bands in *cestata*. When 56 out of 57 young borne by banded parents from *Vaihiria* are plain, and 35 out of 39 from *cestata* parents of *Vairaharaha* are also unbanded, no alternative explanation is reasonable. Certainly it is not justifiable to regard the recorded observations as indicating a secular change in the direction of colonies made up solely of *phæa* individuals.

TABLE 184.—*Partula otaheitana sinistrorsa*. *Vaihiria* and *Vairaharaha* Valleys.

FECUNDITY.								
Series.	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Per cent for gravid.	Per cent for all.
<i>Vaihiria, cestata</i> .....	258	200	77.5	260	57	317	1.58	1.23
<i>Vaihiria, phæa</i> .....	23	20	86.9	27	7	34	1.70	1.48
<i>Vaihiria, all</i> .....	281	220	78.3	287	64	351	1.59	1.25
<i>Vairaharaha, cestata</i> ...	44	42	95.4	53	39	92	2.19	2.09
<i>Vairaharaha, phæa</i> ....	182	160	87.9	224	132	356	2.22	1.96
<i>Vairaharaha, all</i> .....	226	202	89.4	277	171	448	2.22	1.98
HEREDITY. VAIHIRIA VALLEY.						HEREDITY. VAIRAHARAHA VALLEY.		
	Young, banded.	Young, plain.	Total.			Young, banded.	Young, plain.	Total.
Adults:								
<i>cestata</i> .....	1	56	57	4	35	39		
<i>phæa</i> .....	..	7	7	..	132	132		
Total.....	1	63	64	4	167	171		

#### FAARAH VALLEY.

This valley runs parallel to *Vairaharaha*, from which it is well separated by a high and continuous spur of the mountain mass. In two different years journeys were made to this area; in 1907 *Partula hyalina*, *P. clara*, and *P. otaheitana sinistrorsa* were taken. In 1909 a close search was made for *P. producta*, and less attention was paid to the other species, but fortunately a representative collection of *sinistrorsa* was obtained from the middle part of the valley, where it differs somewhat from the series of 1907, taken in the lower valley.

The snails taken in 1909 were exclusively sinistral; those of 1907 were also reversed, with the exception of only two individuals. At first sight, the last-mentioned specimens might be mistaken for *P. producta*, which was found in this valley and here only; but the resemblance is superficial, and disappears when the details of structure and color are taken into account.

As in the neighboring valleys, two color-classes are represented. Banded snails corresponding in general with *cestata* constitute 33 per cent of the collection from the lower valley and 38.6 per cent of the more inland series. Aside from variations in size, well indicated by the specimens figured (plate 31, figs. 35 to 38), a distinct color-type is displayed, where, instead of a zonate medium band, there is a narrow revolving stripe of dark brown (figs. 35, 36); the narrowed band corresponds in position with the lower, or morphologically right, portion of a zonate marking.

The unbanded shells (plate 31, figs. 29 to 34) also display considerable variation in size and form, but even more in the ground-colors; indeed, this division is heterogeneous to an unusual degree. Some shells (fig. 29) are typical rich seal brown, like the original *phæa* of the colonies already treated; from this extreme they grade through progressively lighter conditions, with or without strigations, to shells that approach *apex* of *Titaviri* (fig. 33), which, as we have seen, possesses a somewhat darkened color on the larger whorls. A novel feature is the "fleshy" cast in many cases (fig. 34). Decortication also produces a peculiar appearance, especially in the case of a strigated shell (plate 31, fig. 32). Taking the unbanded class as a whole, it may be regarded as *phæa*, but it displays wider variations; its general average of tone is light on account of the paucity of the original dark shells, while the strigated subtype attains greater prominence than before. From what follows it seems certain that the condition observed here is transitional to that of bandless classes to the west, which have subordinate color-types more clearly differentiated from one another.

The dextral specimens assigned to *sinistrorsa* are different from one another. The first (plate 31, fig. 40) is a typical *cestata*, with bands that do not agree at all with those of *P. producta*; furthermore, its single embryo was *sinistral*. The bandless specimen (plate 31, fig. 39) is more or less like unstriped *producta* as well as light-colored *phæa*, but in form it agrees with the latter only.

The statistics (table 185) show that the two color-divisions do not differ greatly in either of the two series. When these latter are compared, however, it appears that the shells of the lower valley (1907) are collectively longer, wider, and stouter, with longer, wider, and squarer apertures, as compared with those of the inward locality. The proportion of aperture-length to shell-length is substantially the same, and the tooth averages about the same in degree of development.

Fecundity (table 186) is noticeably higher for the 1907 collection. The figures do not indicate with reliability a positive advantage in favor of a particular color-class in the way of differential fertility.

In the heredity of color-characters (table 187) the individuals with unbanded shells prove to be the more conservative. The *cestata* snails produce a comparatively high percentage of unbanded young, so that the total numbers of the two types among the young agree quite closely with the figures for the gravid adults. It is worthy of note that the single young snail produced by the dextral banded adult was banded like its parent, but was *sinistral*! The two directly coiled individuals are presumably sporadic mutants from the *sinistral* series, and not migrants from a distant colony comprising a large number of dextral individuals.

TABLE 185.—*Partula otaheitana sinistrorsa*. Faarahi Valley.

MEAN VALUE.									
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index. <sup>1</sup>
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
		mm.	mm.	p. ct.	mm.	mm.	p. ct.	p. ct.	
cestata, dex., 1907.	1	20.45	11.70	57.5	10.70	8.10	75.5	51.5	1
phæa, dex., 1907..	1	21.35	11.70	54.5	10.70	8.10	75.5	49.5	1
cestata, sin., 1907.	92	20.6065 ± .0652	11.2804 ± .0362	54.6631 ± .1411	10.3174 ± .0389	7.8696 ± .0288	76.3043 ± .1901	50.0109 ± .1229	1.0435 ± .0463
phæa, sin., 1907..	184	20.4288 ± .0503	11.2739 ± .0238	55.1576 ± .1103	10.2739 ± .0265	7.8598 ± .0210	76.4076 ± .1236	50.3098 ± .0952	1.0761 ± .0168
All, sin., 1907...	276	20.4880 ± .0408	11.2761 ± .0199	54.9928 ± .0877	10.2971 ± .0218	7.8630 ± .0162	76.3732 ± .1040	50.2102 ± .0759	1.0652 ± .0122
cestata, sin., 1909.	73	19.5747 ± .0676	10.6151 ± .0336	54.1438 ± .1644	9.8151 ± .0425	7.3959 ± .0272	75.3219 ± .2080	50.0890 ± .1489	1.0411 ± .0505
phæa, sin., 1909..	112	19.4964 ± .0547	10.5893 ± .0285	54.3393 ± .1529	9.7196 ± .0298	7.3804 ± .0229	75.8571 ± .1718	49.6964 ± .1271	1.1810 ± .0303
All, sin., 1909...	185	19.5273 ± .0426	10.5995 ± .0218	54.2622 ± .1132	9.7573 ± .0248	7.3865 ± .0190	75.6459 ± .1331	49.8514 ± .0973	1.1270 ± .0198
All, sin. ....	461	20.1025 ± .0333	10.0046 ± .0181	54.6996 ± .0704	10.0805 ± .0184	7.6718 ± .0143	76.0813 ± .0828	50.0662 ± .0601	1.0903 ± .0109
STANDARD DEVIATION.									
cestata, sin., 1907.	92	0.9272 ± .0461	0.5150 ± .0256	2.0069 ± .0998	0.5537 ± .0275	0.4095 ± .0204	2.7036 ± .1344	1.7479 ± .0869	0.6579 ± .0327
phæa, sin., 1907..	184	1.0117 ± .0356	.4784 ± .0168	2.2180 ± .0780	.5338 ± .0187	.4216 ± .0148	2.4862 ± .0874	1.9144 ± .0673	.3373 ± .0119
All, sin., 1907...	276	1.0045 ± .0288	.4909 ± .0141	2.1604 ± .0620	.5378 ± .0154	.3999 ± .0114	2.5612 ± .0735	1.8658 ± .0537	.2999 ± .0086
cestata, sin., 1909.	73	.8563 ± .0478	.4264 ± .0237	2.0829 ± .1162	.5388 ± .0300	.3442 ± .0192	2.6345 ± .1471	1.8860 ± .1053	.6397 ± .0357
phæa, sin., 1909..	112	.8590 ± .0387	.4479 ± .0201	2.3999 ± .1081	.4682 ± .0211	.3591 ± .0162	2.6954 ± .1215	1.9948 ± .0899	.4842 ± .0214
All, sin., 1909...	185	.8591 ± .0301	.4399 ± .0154	2.2822 ± .0800	.4995 ± .0175	.3827 ± .0134	2.6843 ± .0941	1.9620 ± .0688	.4046 ± .0140
All, sin. ....	461	1.0592 ± .0235	.5760 ± .0128	2.2402 ± .0498	.5859 ± .0130	.4571 ± .0101	2.6355 ± .0585	1.9130 ± .0425	.3476 ± .0077

<sup>1</sup>The numbers are: Sinistral, 92, 184; 276. Dextral, 73, 116; 189. All, 465.TABLE 186.—*Partula otaheitana sinistrorsa*. Faarahi Valley. Fecundity

Series.	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.
cestata, dextral, 1907 .....	1	1	....	2	1	3	3	3
phæa, dextral, 1907 .....	1	1	....	3	...	3	3	3
cestata, sinistral, 1907 .....	92	75	81.5	100	73	173	2.31	1.88
phæa, sinistral, 1907.....	184	162	88.0	231	159	390	2.41	2.12
All, sinistral, 1907 .....	276	237	85.9	331	232	563	2.38	2.04
cestata, sinistral, 1909 .....	64	47	73.4	63	26	89	1.89	1.39
phæa, sinistral, 1909 .....	109	90	82.6	145	59	204	2.27	1.87
All, sinistral, 1909 .....	173	137	79.2	208	85	293	2.14	1.69

TABLE 187.—*Partula otaheitana sinistrorsa*. Faarahi Valley. Heredity of color-pattern.

Sinistral.	1907 series.			1909 series.			1907 and 1909.		
	Banded.	Plain.	Total.	Banded.	Plain.	Total.	Banded.	Plain.	Total.
cestata .....	45	28	73	18	8	26	63	36	99
phæa .....	23	136	159	7	52	59	30	188	218
Total .....	68	164	232	25	60	85	93	224	317

## MOAROA AND TAHARUA VALLEYS.

Although these two valleys are entirely independent, their *sinistrorsa* associations present so many features in common that they may be taken together. The snails of the second one constitute the last colony of *sinistrorsa* proper, for beyond them the shells belong to *sinistralis*.

The color-types represented are *cestata* and *phæa*. In Moaroa the relative numbers of the two classes were 39.4 and 60.6 per cent, respectively, in a series of 434 adults; they were all sinistral. Three banded *cestata* were taken in Taharua; of the 322 sinistral snails, 35.7 per cent were *cestata* and 64.3 per cent were unbanded. The figures for the relative abundance of the two classes are thus substantially alike.

Taking the Moaroa colony first, the *phæa* division is quite heterogeneous, as in Faarahi, for the shells grade from rich dark-brown (*solida*) through *confluens* to strigated (*striata*), and finally clearer lighter-brown (plate 31, figs. 41 to 46). A very peculiar giant adolescent was secured here (plate 31, fig. 47) that greatly exceeds the largest adult in size. The medium and darker shells amount to 227, while the lighter variants number 36. Shells of the *cestata* are also variable, sometimes exhibiting much lightened and narrowed bands on a clearer background, sometimes becoming almost solid brown by the suffusion and extension of the revolving stripes (plate 31, figs. 48 to 51). An unusually small or "dwarfed" shell is shown in figure 51. Just as the *phæa* class becomes resolved into more clearly demarcated subdivisions in passing onward to the western *sinistralis* series, so *cestata* breaks up into subordinate orders in more western valleys, as we shall see at a later point.

Passing to Taharua, we find *phæa* centering about three grades of intensity. Out of 207 specimens, 19 are very light, clear, horny yellow (plate 31, figs. 52 and 53), 121 are medium, and 67 are dark *confluens*. It is possible that the first subdivision is really equivalent to *apex* without the dark coloring of the spire, but it is more probable that they are highly modified members of the *phæa* color-class. The *cestata* class is composite, as in Moaroa; plate 31, figure 54 shows a very dark example. The lighter tone is exhibited by two of the dextral *cestata* (plate 31, fig. 55), while the third (plate 31, fig. 56) exhibits much suffusion of the stripes.

As in their color-composition, so in their dimensions and proportions (table 188) the two associations are very similar. In each case, also, the two constituent color-classes agree closely. The aberrant dextral individuals of Taharua depart greatly from the average conditions of the prevalent sinistral series, so far as the absolute dimensions are concerned, but their proportionate measures are not distinctive. Even in statistical respects they prove to be related to the rest, while positive but meager data of heredity establish their genetic relationship beyond a doubt.

It so happens that both collections were made in 1906, during the wet season. As might be expected from the facts given heretofore, the rate of productivity was low (table 189), both as regards the numbers of gravid adults and also the numbers of embryonic individuals.

TABLE 188.—*Partula otaheitana sinistrorsa*. *Moaroa and Taharua Valleys*.

MEAN VALUE.									
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index. <sup>1</sup>
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
Moaroa, cestata, sin .. phæa, sin ....	169	<i>mm.</i> 18.5772 ± .0432	<i>mm.</i> 10.3083 ± .0203	<i>p. ct.</i> 55.4350 ± .1074	<i>mm.</i> 9.4420 ± .0227	<i>mm.</i> 7.2041 ± .0187	<i>p. ct.</i> 76.2811 ± .1304	<i>p. ct.</i> 50.7308 ± .0864	1.3567 ± .0315
	263	18.6842 ± .0326	10.3525 ± .0162	55.3365 ± .0962	9.4688 ± .0173	7.2331 ± .0128	76.3403 ± .0997	50.6749 ± .0773	1.2890 ± .0254
Moaroa, all, sin. ....	432	18.6424 ± .0261	10.3352 ± .0127	55.3750 ± .0721	9.4583 ± .0138	7.2218 ± .0107	76.3171 ± .0793	50.6968 ± .0579	1.3157 ± .0191
Taharua, cestata, sin .. phæa, sin ...	115	18.5587 ± .0529	10.3830 ± .0266	55.8652 ± .1217	9.5104 ± .0330	7.2252 ± .0248	75.8217 ± .1770	51.1261 ± .1063	1.4000 ± .0387
	205	18.5739 ± .0336	10.3478 ± .0186	55.6809 ± .0954	9.4809 ± .0211	7.2151 ± .0164	75.9585 ± .1261	50.9780 ± .0838	1.3333 ± .0295
Taharua, all, sin. ....	320	18.5684 ± .0287	10.3606 ± .0153	55.7469 ± .0752	9.4913 ± .0180	7.2188 ± .0138	75.9094 ± .1028	51.0313 ± .0660	1.3571 ± .0235
Taharua, cestata, dex. .	3	18.0500 ± .3304	9.8323 ± .1942	54.8333 ± .6618	9.1667 ± .2233	6.6333 ± .1973	75.5000 ± .0	50.5000 ± .6359	3.0000 ± .3180
STANDARD DEVIATION.									
Moaroa, cestata, sin .. phæa, sin ....	169	0.8336 ± .0305	0.3918 ± .0143	2.0702 ± .0759	0.4381 ± .0160	0.3602 ± .0132	2.5125 ± .0922	1.6641 ± .0611	0.5580 ± .0223
	263	.7854 ± .0230	.3902 ± .0114	2.3137 ± .0751	.4169 ± .0122	.3077 ± .0090	2.3137 ± .0751	1.8580 ± .0546	.6105 ± .0179
Moaroa, all, sin. ....	432	.8063 ± .0184	.3914 ± .0090	2.2221 ± .0510	.4255 ± .0097	.3295 ± .0076	2.4431 ± .0561	1.7849 ± .0409	.5913 ± .0135
Taharua, cestata, sin .. phæa, sin ...	115	.8412 ± .0374	.4229 ± .0188	1.9352 ± .0860	.5254 ± .0233	.3951 ± .0175	2.8147 ± .1251	1.6912 ± .0752	.6157 ± .0274
	205	.7145 ± .0237	.3949 ± .0131	2.0246 ± .0674	.4472 ± .0149	.3489 ± .0116	2.6768 ± .0891	1.7795 ± .0592	.6294 ± .0208
Taharua, all, sin. ....	320	.7625 ± .0203	.4055 ± .0108	1.9949 ± .0532	.4771 ± .0127	.3662 ± .0097	2.7279 ± .0727	1.7497 ± .0467	.6251 ± .0166
Taharua, cestata, dex. .	3	.8485 ± .2336	.4988 ± .1373	1.6996 ± .4679	.5735 ± .1579	.5068 ± .1395	0	1.6329 ± .4496	.8165 ± .2249

<sup>1</sup>The numbers are, respectively, 171, 263; 434 : 115, 207; 322.TABLE 189.—*Partula otaheitana sinistrorsa*. *Moaroa and Taharua Valleys*. *Fecundity*.

Series.	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.
Moaroa, cestata, sin. .... phæa, sin. ....	167	93	55.7	100	35	135	1.45	0.81
	262	166	63.4	178	56	234	1.41	0.89
Moaroa, all, sin. ....	429	259	60.4	278	91	369	1.42	0.86
Taharua, cestata, sin. .... phæa, sin. ....	115	70	60.9	89	25	114	1.63	0.99
	206	110	53.4	136	38	174	1.58	0.84
Taharua, all, sin. ....	321	180	56.1	225	63	288	1.60	0.90
Taharua, cestata, dex. ....	3	2	66.6	3	0	3	1.50	1.00

TABLE 190.—*Partula otaheitana sinistrorsa*. *Statistics of heredity*.

	Moaroa Valley.			Taharua Valley.			Total.
	Banded, sinistral.	Plain, sinistral.	Total.	Banded, sinistral.	Plain, sinistral.	Plain, dextral.	
cestata, sin. ....	21	14	35	6	19	....	25
phæa, sin. ....	9	47	56	0	37	1	38
Total. ....	30	61	91	6	56	1	63

The data of heredity (table 190) are consistent for the Moaroa association. In the Taharua series there is a great preponderance of young with unbanded shells, no doubt owing to the attenuation of bands and their late appearance in development. One plain and dextral snail was produced by a sinistral phæa; this fact proves the origin of directly coiled snails by mutation from sinistral parents.



## THE MENDELIAN INHERITANCE OF THE COLOR-PATTERNS.

The variety *sinistrorsa* exhibits two primary forms of coloration in nearly every valley of its occurrence, namely, the plain and the banded; as in the case of *affinis*, therefore, an opportunity is presented for an inquiry into the phenomena of heredity, to ascertain whether these two forms are Mendelian alternatives in nature and behavior. It is true that the unbanded classes named *apex* and *phæa* are not alike in details, but they form a single group in contrast with the *cestata* class, for the purposes of the inquiry.

For one reason or another, the available material is reduced to the colonial statistics of four valleys, namely, Tenaire, Maara, Faarahi, and Moaroa. The Titaviri data are useless because there is no record of even a single banded shell among the young; in Vaipoe, on the contrary, all of the young of *cestata* are banded. Too often the striped class is so poorly represented in both the adult population and the embryonic series as to make an analysis fruitless or impossible. Four independent valley series remain, and their analysis must possess some degree of positive value, especially because the two characters under consideration are precisely the same as in the case of *affinis*. Furthermore, in Tenaire and Maara there are two kinds of plain shells, as well as dextral representatives of all classes, whereas in Faarahi and Moaroa the material includes only sinistral *phæa* and *cestata*; hence there is sufficient diversity of material to render the general consistency of the results obtained all the more significant.

## TENAIRE VALLEY.

As stated above, the material in this case is complex, but fortunately it is abundant. The fundamental data relating to the numerical proportions of the two classes in the population are as follows:

	Plain.	Banded.
Whole population.....	674/907 = 74.1 p. ct.	233/907 = 25.8 p. ct.
Sinistral.....	265/374 = 70.8 p. ct.	109/374 = 29.1 p. ct.
Dextral.....	409/533 = 76.7 p. ct.	124/533 = 23.2 p. ct.

Gravid parents with distinguishable young are classified as follows:

	Plain young.	Plain and banded young.	Banded young.	Total.
Whole series:				
Plain.....	404	6	38	448
Banded.....	63	10	84	157
Sinistral series:				
Plain.....	135	4	23	162
Banded.....	22	6	42	70
Dextral series:				
Plain.....	269	2	15	286
Banded.....	41	4	42	87

In the absence of certainty as to the interbreeding of sinistral and dextral snails, the analysis of the whole combined series is less useful than that of either component group taken by itself; but, nevertheless, the former has a value not only because larger figures are available, but also because natural errors in one series would tend

to be offset in part by discrepancies in the other, on the law of chances. Hence, we may deal with the three series in the above order, without reviewing all of the steps in the process, which is precisely the same as in the cases of *rubescens* and *affinis*.

First, assuming that banding is recessive, the empirical proportions of DD, DR, and RR mates of the *cestata* individuals prove to be 31:85:41, which are significantly probable; the correction of the first and third class figures is  $\frac{43}{84}$ , again a probable fraction in view of the great number of adults that bear only one young snail apiece. When these data are used to test the correspondence between theory and observation in the case of the plain parents, the expected numbers in the group bearing plain young only and in the group bearing both plain and banded young are 185:263, as compared with the empirical figures of 197:251; the difference amounts to 12 in 448, or 2.7 per cent.

Making the assumption that absence of bands is recessive, and inverting the tables, the numbers of DD, DR, and RR prove to be the improbable figures 31:85:332. Pursuing the analysis further, in the alternative series, expectation and observation differ to the extent of 19 in 157, or 12.1 per cent. There are two reasons for regarding the former assumption as the more tenable, when the fundamental hypothesis is made as to the Mendelian order of inheritance.

Next, the sinistral series may be taken by itself, when, under the first assumption as to the recessiveness of banding, the proportions of DD, DR, and RR prove to be 11:39:20, with an indicated correction of  $\frac{22}{42}$ . Theory and observation, in the independent test, differ by 5.5 per cent. Supposing plainness to be recessive, the three genetic classes would be as 20:27:115, which are improbable proportions; it is true that expectation and empirical determination differ by only 2 in 70, or 2.8 per cent, which, however, only partially offsets the unnaturalness of the proportionate relations specified.

Turning now to the fuller dextral series, and proceeding first on the basis of the dominance of the plain pattern, we find that DD, DR, and RR are as 20:47:20, and that the independent test gives a departure of observation from theory of only 3 in 286, or 1.05 per cent. When the contrary supposition is made as to the relative values of plainness and banding, the analysis breaks down, because the expected numbers of RR×RR is 77 per cent of 286, or 220, which exceeds the actual number of banded parents with only banded young, viz, 169.

In brief, the Tenaire material is very complex, and the results are not entirely consistent, but there is a preponderance of evidence (1) that the phenomena are Mendelian, and (2) that the absence of bands is dominant to their presence.

#### MAARA VALLEY.

The colony is quite as complex as before, while there are additional difficulties due to small numbers. The numbers of plain and banded snails are as follows:

	Plain.	Banded.
Whole population. . . . .	91/203 = 44 p. ct.	112/203 = 55 p. ct.
Sinistral population. . . . .	57/133 = 42.8 p. ct.	76/133 = 57 p. ct.
Dextral population. . . . .	36/72 = 50 p. ct.	36/72 = 50 p. ct.

The gravid parents are represented numerically in the three classes, thus:

	Plain young.	Plain and banded young.	Banded young.	Total.
Whole series:				
Plain.....	41	1	3	45
Banded.....	11	2	49	62
Sinistral series:				
Plain.....	26	0	3	29
Banded.....	8	1	31	40
Dextral series:				
Plain.....	15	1	0	16
Banded.....	3	1	18	22

Considering first the whole series, the departure of the empirical figure from expectation amounts to 26.6 per cent, under the assumption that banding is a Mendelian recessive, while the corresponding difference is 30.6 per cent under the contrary hypothesis.

In the analysis of the sinistral series alone, the differences are 34.4 and 27.5 per cent, respectively; in the case of the dextral series the difference under the first assumption is 31.2 per cent, but the contrary hypothesis leads to an abrupt halt, in so far as no double dominants would be indicated as existing. Here again, then, the facts tend to prove the same two points as in the case of the Tenaire analysis.

#### FAARAHĪ VALLEY.

Only *phæa* and *cestata* are represented in this population, which is sinistral in a series of 465 adults, although one dextral individual of each class also was found; naturally these last can be disregarded. Plain shells amounted to 65 per cent, and banded to 35 per cent. The classified parents are as follows:

Plain adults: plain young, 138; both kinds, 9; banded young, 18=165

Banded adults: plain young, 25; both kinds, 5; banded young, 48=78

Taking the banded pattern as recessive, the proportion of DD, DR, and RR mates of the snails exhibiting that character are 14:37:27, after an adjustment to the extent of  $\frac{21}{48}$  of the number in the first and third classes; the figures are not improbable. Carrying out the analysis of the plain parents, expectation gives 66:99, and corrected observation gives 78:87, for the class with plain young only and the class with both kinds. The difference amounts to  $\frac{12}{165}$  or 7.27 per cent.

On the supposition that banding is dominant, the figures for the three genetic classes are 15:33:107, which are obviously unnatural, and the difference in the independent test amounts to 23 in 78, or 29.5 per cent. The findings are in clearer accord with the former assumption, and with Mendelism as a working hypothesis.

#### MOAROA VALLEY.

Again the material is simple, as all of the snails are sinistral, and apex is absent. Plain shells amount to 61 per cent and the banded to 39 per cent of the adult population, comprising 434 individuals. The classified parents are as follows:

Plain adults: plain young, 47; both kinds, 0; banded young, 9=56

Banded adults: plain young, 13; both kinds, 0; banded young, 20=33

Analyzing the material of the second line, on the assumption that banding is recessive, the proportions of the genetic classes are as 8:12:13, which give a departure of only 1 in 56, or 1.8 per cent in the corroborative test. Supposing the contrary, the proportions are the less satisfactory figures, 9:13:34, with an indicated difference of 6.06 per cent in the further analysis.

## RÉSUMÉ.

The general results, combined in table 191, lend considerable support to the contention that the unbanded pattern is dominant to the banded form of coloration in a Mendelian order of inheritance. In view of the many difficulties involved, it is not to be expected that the results would be more consistent than they prove to be in this case.

TABLE 191.—*Partula otaheitana sinistrorsa*. Summary of the results of a Mendelian analysis of the color-patterns in heredity.

Series.	Assuming <i>plain</i> as dominant.		Assuming <i>banded</i> as dominant.	
	Proportions of DD : DR : RR.	Difference in independent test.	Proportions of DD : DR : RR.	Difference in independent test.
Tenaire:		<i>p. ct.</i>		<i>p. ct.</i>
Combined.....	31 : 85 : 41	2.7	31 : 85 : 332	12.1
Sinistral.....	11 : 39 : 20	5.5	20 : 27 : 115	2.8
Dextral.....	20 : 47 : 20	1.05	Impossibility.	.....
Maara:				
Combined.....	8 : 20 : 34	26.6	2 : 23 : 20	30.6
Sinistral.....	6 : 11 : 23	34.4	1 : 16 : 12	27.5
Dextral.....	2 : 9 : 11	31.2	Impossibility.	.....
Faarahi, sinistral.....	14 : 37 : 27	7.3	15 : 33 : 107	29.5
Moaroa, sinistral.....	8 : 12 : 13	1.8	7 : 15 : 34	6.06

## SUMMARY AND CONCLUSION.

The series herein described as *Partula otaheitana sinistrorsa* grades so directly into *P. o. sinistralis*, and this in turn is so similar to *P. o. crassa*, that a summary discussion might well be deferred until all of the colonies as far as Taapuna had been described. In that case, however, there would be 34 associations to be considered. It is preferable, therefore, to consider the three divisions separately, always emphasizing their closer relationship, which in the case of the *sinistrorsa-sinistralis* transition almost amounts to continuity.

I. The colonies of *P. o. sinistrorsa* vary from valley to valley (1) in their relative numbers in the whole population; (2) in the proportionate numbers of sinistral and dextral individuals, when the latter occur; (3) in the relative numbers assigned to the several color-classes, and (4) in details of color-variation within one or another color-class. It is unnecessary to repeat at length the statements of earlier general discussions as to the significance of such variations. While the Taiarapu areas may differ ecologically to some slight degree, the valleys of southern Tahiti nui are similar in every observable respect; in no case are there discoverable environmental factors that might account for the special features of a *sinistrorsa* colony in a single

valley. Indeed, *affinis* exists in five valleys in company with *sinistrorsa*, and it would be impossible to attribute the origin of *two* distinct primary varieties to one and the same group of extraneous influences. The color-classes apex and phæa do not occur everywhere; dextral mutants appear in numbers in three successive valleys, and then they disappear, to recur in Faarahi and again in Taharua. In these cases, also, it is not reasonable to attribute the positive presence of a type to a cause other than a congenital one.

II. *The average dimensions and proportions of the shells vary from valley to valley, without any consistent relation to environmental influences or to geographical sequence.* Disregarding the dextral elements in certain specified cases, the figures for the sinistral colonies are given serially in table 192, while the differences with their probable errors are enumerated in table 193. The graphic presentation (table 194) gives the ranges of the several characters, in the whole series of valleys, as well as the averages and the fluctuations of the latter in geographical order. The Taiarapu colonies are made up of very large shells on the average; but rainfall and humidity,

TABLE 192.—*Partula otaheitana sinistrorsa*. Colonial statistics of sinistral shells. Mean value.

Valley.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
		mm.	mm.	p. ct.	mm.	mm.	p. ct.	p. ct.	
Vaiaaia.....	137	20.1237±.0430	11.2212±.0260	55.6679±.1183	10.4328±.0257	7.8255±.0212	74.9818±.1519	51.8212±.0962	1. ±.0
Aiavaro.....	168	20.1250±.0483	11.0750±.0224	55.0595±.1090	10.1202±.0261	7.6655±.0202	75.6905±.1351	50.3036±.0889	1. ±.0
Vavii.....	219	21.3979±.0428	11.4416±.0236	53.4315±.1030	10.6507±.0229	7.8927±.0188	74.0936±.1120	49.7466±.0762	1. ±.0
Vaipoe.....	190	21.8111±.0483	11.4558±.0242	52.4106±.1070	10.7894±.0276	7.8915±.0207	73.0474±.1242	49.4000±.0867	1. ±.0
Apirimaue....	284	19.3926±.0371	10.6993±.0200	55.1021±.0953	9.6042±.0198	7.1810±.0152	74.7958±.1080	49.4014±.0737	1. ±.0
Titaviri.....	165	19.7500±.0483	10.9073±.0264	55.1697±.1426	10.1267±.0249	7.5715±.0215	74.7788±.1629	51.2636±.0991	1.0774±.0188
Tenaire.....	364	19.1033±.0338	10.6813±.0162	55.8406±.0874	9.8242±.0180	7.4522±.0136	75.8956±.0932	51.3599±.0688	1.0296±.0065
Maara.....	132	18.0045±.0473	10.3091±.0264	57.1212±.1381	9.1276±.0284	7.0727±.0214	77.4697±.1704	50.7121±.1124	1.1052±.0193
Vaihiria.....	303	18.2738±.0300	10.2314±.0154	55.9455±.0813	9.2399±.0157	7.0881±.0120	76.5792±.0970	50.4934±.0668	1. ±.0
Vairaharaha..	247	18.0949±.0325	10.1202±.0174	55.8887±.0900	9.2539±.0191	7.0506±.0139	75.9818±.1085	51.0830±.0741	1. ±.0
Faarahi.....	461	20.1025±.0333	11.0046±.0181	54.6996±.0704	10.0805±.0184	7.6718±.0143	76.0813±.0828	50.0662±.0601	1.0903±.0109
Moaroa.....	432	18.6424±.0261	10.3352±.0127	55.3750±.0721	9.4583±.0138	7.2218±.0107	76.3171±.0793	50.6968±.0579	1.3157±.0191
Taharua.....	320	18.5684±.0287	10.3606±.0153	55.7469±.0752	9.4913±.0180	7.2188±.0138	75.9094±.1028	51.0313±.0660	1.3571±.0235

which favor growth, are no greater there than in the districts of Mataiea and Papeari, where the shells are smaller. In the southern sector the size fluctuates as one passes westward, without any relation to the size of the valley, differences in vegetation, etc. Likewise the proportionate measures vary inconsistently. Passing from Apirimaue to Titaviri, the shells become longer, the apertures increase in length, and the latter become far longer within reference to the former; but in the passage from Vairaharaha to Faarahi, where shell-length and aperture-length increase as before, the proportionate figure diminishes. Local variations in the degree of the tooth development are even less attributable to anything but congenital influences.

III. *It is impossible to determine whether the colonies of Taiarapu have been founded by migrants from Tahiti nui, or by snails introduced on vegetation carried by human beings.* The prior point is that *sinistrorsa* was formerly absent from the peninsula, for which the evidence has been given. It is true that on rare occasions

a native will secure young plantains from one valley for establishment in a region nearer his home, although the wild plants are usually abundant everywhere. In such a case, any *Partula* that were sealed up upon the young leaves might remain attached and so be transported to a valley where its kind did not exist. Assuming them to be already gravid, or assuming that several animals were thus carried to a new place, the type might thus be established in another region.

TABLE 193.—*Partula otaheitana sinistrorsa*. Progressive geographical comparisons. Differences in mean value.

Valley.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index.
	Length.	Width.	Proportions.	Length.	Width.	Proportions.		
Vaiaia . . . . .	<i>mm.</i> [+0.0013±.0646]	<i>mm.</i> -0.1462±.0343	<i>p. ct.</i> -0.6084±.1608	<i>mm.</i> -0.3126±.0366	<i>mm.</i> -0.1600±.0293	<i>p. ct.</i> +0.7087±.2032	<i>p. ct.</i> -1.5176±.1310	[0]
Aiavaro . . . . .	+1.2729±.0645	+ .3666±.0325	-1.6280±.1499	+ .5305±.0347	+ .2272±.0276	-1.5969±.1755	- .5570±.1171	[0]
Vavii . . . . .	+ .4132±.0645	[+ .0142±.0323]	-1.0209±.1485	+ .1387±.0359	[-.0012±.0279]	-1.0462±.1672	- .3466±.1154	[0]
Vaipoe . . . . .	-2.4185±.0609	- .7565±.0314	+2.6915±.1433	-1.1852±.0340	- .7105±.0257	+1.7484±.1646	[+ .0014±.1138]	[0]
Apirimaue . . . . .	+ .3574±.0609	+ .2080±.0331	[+ .0676±.1715]	+ .5225±.0318	+ .3705±.0263	[- .0170±.1954]	+1.8622±.1235	+0.0774±.0188
Titaviri . . . . .	- .6467±.0589	- .2260±.0301	+ .6709±.1672	- .3025±.0307	- .1193±.0254	+1.1168±.1877	[+ .0963±.1206]	- .0478±.0199
Tenaire . . . . .	-1.0988±.0590	- .3722±.0310	+1.2806±.1634	- .6966±.0336	- .3795±.0253	+1.5741±.1942	- .6478±.1318	+ .0756±.0203
Maara . . . . .	+ .2693±.0560	- .0777±.0305	-1.1757±.1602	+ .1123±.0325	[+ .0154±.0245]	- .8905±.1961	[- .2187±.1307]	- .1052±.0193
Vaihiria . . . . .	- .1789±.0442	- .1112±.0232	[- .0568±.1213]	[+ .0140±.0247]	- .0375±.0184	- .5974±.1455	+ .5896±.0997	[0]
Vairaharaha . . . . .	+2.0076±.0465	+ .8844±.0251	-1.1891±.1143	+ .8266±.0265	+ .6212±.0199	[+ .0995±.1365]	-1.0168±.0954	+ .0903±.0109
Faarahi . . . . .	-1.4601±.0423	- .6694±.0221	+ .6754±.1008	- .6222±.0230	- .4500±.0179	+ .2358±.1146	+ .6306±.0834	+ .2254±.0220
Moaroa . . . . .	[- .0740±.0388]	[+ .0254±.0199]	+ .3719±.1042	[+ .0330±.0227]	[- .0030±.0174]	- .4077±.1298	+ .3345±.1072	[+ .0414±.0303]
Taharua . . . . .	-1.3048±.0377	- .4384±.0200	+1.6196±.1014	- .6119±.0227	- .4549±.0176	[+ .1967±.1324]	+ .3090±.0879	+1.3226±.0330
[Teohu] . . . . .								

Yet the facts as observed are explicable on either of the assumptions stated:

(1) The Taiarapu shells are exclusively sinistral. Migrants from Tahiti nui would be sinistral on the law of chances, because this is the prevalent mode of coil; but snails brought passively on vegetation would also be preponderatingly reversed.

(2) The Taiarapu snails are exceedingly large, on the average. Only well-grown and vigorous individuals could successfully traverse the drier region of the isthmus so as to reach Taiarapu; but again only large snails would be likely to survive the interval between the cutting of a plantain secured in Tahiti nui and its replanting in a Taiarapu valley.

(3) The three color-classes of Mataiea valleys are not represented in all of the peninsula area; whether brought by their efforts or by human agency, the first *sinistrorsa* inhabitants in Taiarapu would naturally be few, and would scarcely be representative of all the color-classes. Were they pure *cestata*, their offspring would multiply in time to become like the Vavii colony; were they mixed in gametic constitution, their descendants would segregate out into two or more class-types,

TABLE 194. *Partula otaheitana sinistrorsa*. Progressive variation of the colonies in geographical order, as regards range and mean value. (Sinistral shells, full lines; dextral shells, interrupted lines.)

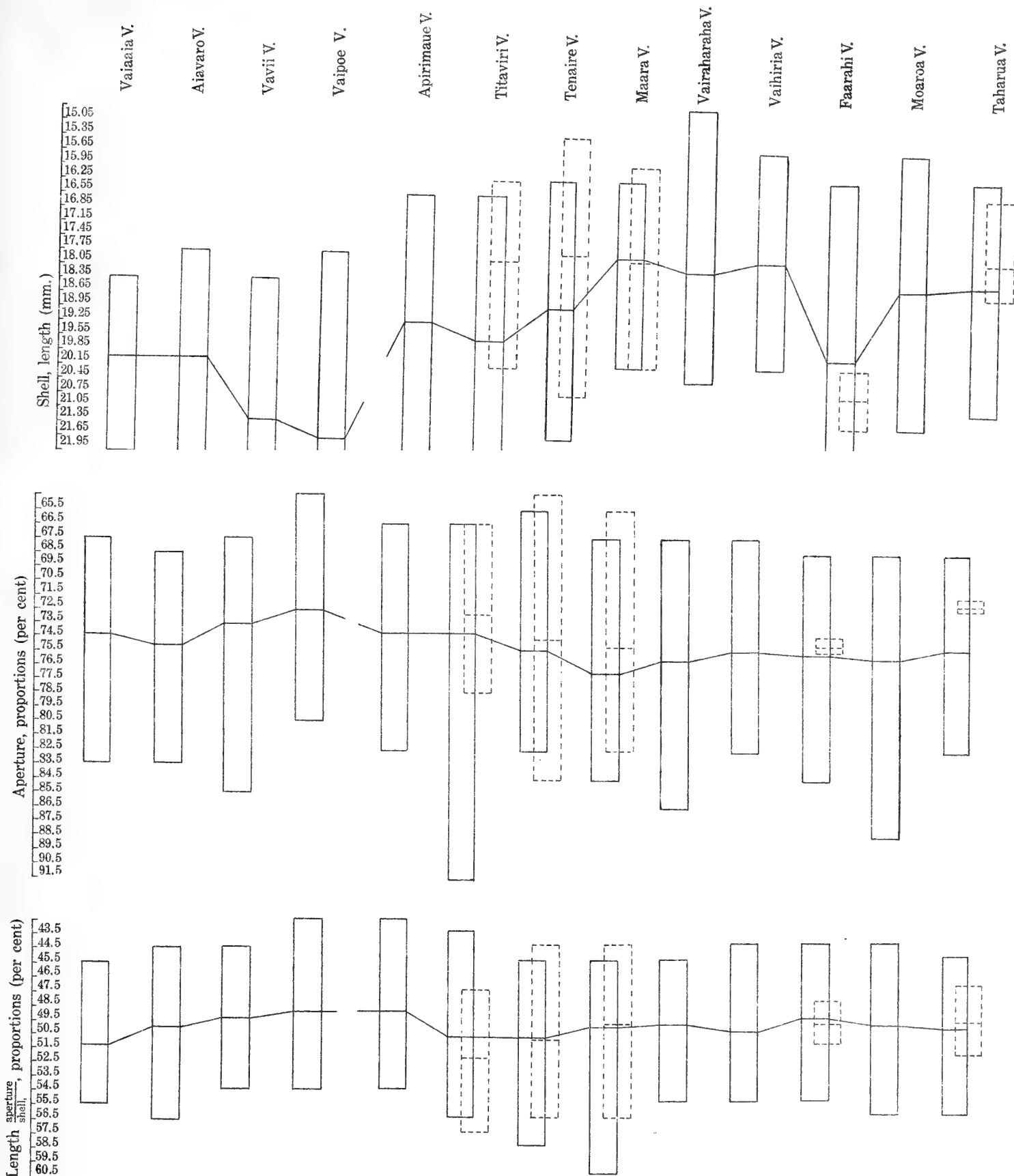
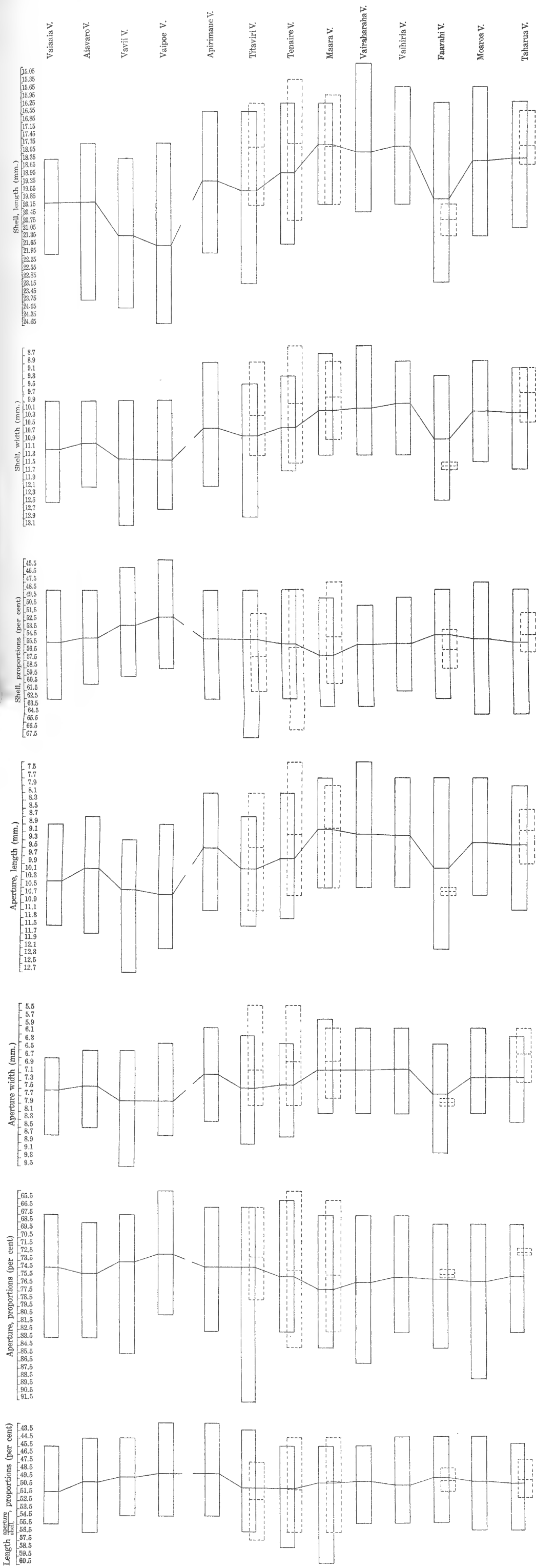






TABLE 194. *Partula otaheitana sinistrorsa*. Progressive variation of the colonies in geographical order, as regards range and mean value. (Sinistral shells, full lines; dextral shells, interrupted lines.)





as in the other valleys of the peninsula. Under this head, there are certain facts that militate against the migration hypothesis; the nearest valley to Tahiti nui lacks *sinistrorsa*, the next has two classes, the succeeding valley only one, and the most eastward association includes all three. If, now, the last-named colony was founded by snails that had reached Vaiaaia by their own efforts, we ought to find *phæa* as well as *apex* in the intervening area. It is still possible, nevertheless, that the peopling of Tairapu took place by migration some time ago, and that subsequently *phæa* disappeared from all but the Vaiaaia colony, and *apex* from Vavii. In brief, when due weight is given to all of the pertinent biological and geographical considerations, the question at issue remains unsettled.

TABLE 195.—*Partula otaheitana sinistrorsa*. Collective description, sinistral shells.<sup>1</sup>

Character.	Mean value.		Standard deviation.	
	Combined series.	Average of valley types.	Combined series.	Average of valley types.
Shell, length, mm.....	19.3845 ± .0161	19.4915	1.3949 ± .0114	0.8744
width, mm.....	10.7015 ± .0072	10.7571	.6239 ± .0051	.4604
proportions, p. ct.....	55.1979 ± .0284	55.1892	2.4633 ± .0201	2.2439
Aperture, length, mm.....	9.8033 ± .0079	9.8615	.6872 ± .0056	.4856
width, mm.....	7.4162 ± .0055	7.4464	.4786 ± .0039	.3786
proportions, p. ct....	75.6373 ± .0323	75.5094	2.8003 ± .0228	2.6467
Length aperture ÷ length shell proportions, p. ct.....	50.5368 ± .0223	50.5676	1.9312 ± .0158	1.7931
Tooth, index.....	1.0964 ± .0041	1.0750	.3573 ± .0029	.1878

<sup>1</sup>The number of individuals is 3,422; tooth 3,445.

IV. *The collective statistical description of sinistrorsa is useful as a basis for its comparison as a whole with other primary varieties.* The collective characters have been already given (table 161) for spirality and color-composition; the quantitative data for the characteristic sinistral shells are presented in table 195. As in the case of other primary varieties, it is permissible to group all individuals into one series, when abundant associations will have more effect on the average figure than collections that comprise fewer shells; the result will be a general specification for the whole series as a part of the *otaheitana* population. In the second place, each colony may be regarded as a genetic unit, and an average of such unit-elements would give a figure with a different biological significance. In the case of *sinistrorsa*, the numbers are large in all valleys, and the two sets of figures do not differ as greatly as in the case of *P. rubescens*. The detailed comparison with other primary varieties may be reserved until the final summary.

V. *The banded pattern seems to be dominant to the absence of bands in a Mendelian order of inheritance.* Although the final proof must be given by actual breeding experiments, yet the evidence at hand is such as to indicate the truth of this statement. It is in accord with the results obtained through the study of *affinis*, as well as with the experimental proof derived from the case of *Helix*, as described by Lang.

*PARTULA* *OTAHEITANA SINISTRALIS* Pease.

## GENERAL CONSIDERATIONS.

Passing westward from Taharua, the last valley occupied by *Partula otaheitana sinistrorsa* proper, we enter the territory of the second group belonging to the triple series now under consideration; this area comprises the larger and smaller valleys from Teohu to Vaipuarii, inclusive. The distinctive peculiarities of the colonies were regarded by Pease as of specific value, and he named the kind *Partula sinistralis*. Garrett's description is their only characterization in the original literature, but Garrett differed from Pease in that he related *sinistralis* to *sinistrorsa*, and indeed, by implication, he subordinated the former to the position of a section of the latter. In the present study *sinistralis* is treated as the second division of the tripartite "sinistral series of the south and west," whose other members are *sinistrorsa* and *crassa*; it is intimately related to both of these and is transitional from the first to the second, in correspondence with the location of its territory between the areas occupied by *sinistrorsa* and *crassa*.

In Garrett's paragraph relating to *sinistralis*, which has already been given (p. 220) without comment, the points of departure from the *sinistrorsa* type are specified sufficiently in a qualitative way; to these the following detailed analysis will add quantitative differentia. The alliance of the two groups is manifested by the predominating reversal of the coil in *sinistralis*, by the absence of ground-colors like those of *rubescens*, by the occurrence of banded forms of marking referable to the *cestata* type among *sinistrorsa*, and by the existence of the color-forms called apex and phæa in certain of the eastward colonies. Other characteristic color-forms make their appearance, which are suggestive of the distinctive *crassa* types found in the western sector of Tahiti nui.

It will appear that *sinistralis* is not always stunted and dentated, as Garrett states, nor is it always sinistral; some of the most western colonies comprise numerous dextral individuals, so that in general composition they come to resemble certain eastern *sinistrorsa* associations. Furthermore, we find *sinistralis* in two large valleys, as Garrett says, but it exists in many lesser topographical elements as well, and even in the coastward forests outside the mouths of the valleys. Undoubtedly Garrett knew that the snails were not confined to the two major valleys situated between Taharua and the southwestern corner of the island, but presumably he ignored the lesser areas and regarded the larger elements as inclusive of the rest.

The line of division between the range of *sinistralis* and that of *sinistrorsa* passes between Taharua and Teohu Valleys, as stated; but there is no topographical feature at that point to account for the abrupt transition from the one kind to the other. On the contrary, one might almost view the valley areas of Taharua and Teohu as continuous, because much forest grows along the coastal face of the buttress between the two clefts, wherein snails are to be found, though in very small numbers. At its western end the *sinistralis* territory extends beyond a well-marked ridge that runs down to the coast at the southwestern corner, so as to include one valley of the western sector, viz, Vaipuarii.

The dominant color-form of *sinistralis* is *cestata*, with some modifications of the bands. Among the unbanded snails one finds apex represented in certain valleys, but in very few. The class that is equivalent to the *sinistrorsa* phæa is sometimes a single highly varying group; more often, however, it is split up into somewhat sharply demarcated color divisions, one of which is the *confluens* described earlier, while the shells of the other are distinctly strigated, like some of the *sinistrorsa* specimens found in Tenaire Valley; as before, the latter color-type will be called *striata* for brevity and convenience. The absolute and relative numbers of the snails referred to these color-classes are given in table 196, which supplements the more general numerical tabulations given in table 56.

TABLE 196.—*Partula otaheitana sinistralis*. Census of the color-forms.

Valley.	Total No. of adults.	Number in adult population.						Per cent of adult population.					
		Sinistral.			Dextral.			Sinistral.			Dextral.		
		apex.	cestata.	phæa.	apex.	cestata.	phæa.	apex.	cestata.	phæa.	apex.	cestata.	phæa.
Teohu <sup>1</sup> ....	459	35	333	91	..	...	..	7.6	72.5	1.9	...	....	...
Papeiti....	475	8	209	258	..	...	..	1.7	44.0	54.3	...	....	...
Temarua..	563	1	365	195	..	2	..	0.2	64.8	34.6	...	0.4	...
Vaipoo....	62	..	49	13	..	...	..	...	79.0	21.0	...	....	...
Tearatapu.	30	..	15	15	..	...	..	...	50.0	50.0	...	....	...
Opiriroa...	152	..	112	40	..	...	..	...	73.7	26.3	...	....	...
Otuna....	347	..	237	110	..	...	..	...	68.3	31.7	...	....	...
Maruia....	129	..	61	43	..	17	8	...	47.3	33.3	...	13.2	6.2
Tereehia...	130	..	58	12	..	60	..	...	44.6	9.2	...	46.1	...
Tiamao....	326	..	169	8	1	138	10	...	51.8	2.4	0.3	42.3	3.1
Vaipuarii..	180	..	142	38	..	...	..	...	78.9	21.1	...	....	...
Total.....	2,853	44	1,750	823	1	217	18	1.5	61.3	28.8	0.03	7.6	0.6

<sup>1</sup>One dextral embryonic snail.

## DESCRIPTION OF THE COLONIES—TEOHU TO VAIPUARI VALLEYS.

## TEOHU VALLEY.

Most of the specimens from this valley were taken in 1906, during the warmer season; a small series was also secured in 1907. The valley is a small one, as the charts and diagrams have shown, and the occurrence of some forest growth between its mouth and those of the adjacent valleys renders it almost continuous with its neighbors. Nevertheless, the Teohu colony of *sinistralis* is most unique. Shells of the apex coloration (plate 31, figs. 57 to 59) amount to 35, some of them displaying the effects of decortication so as to be nearly white, save for the tinted spire (fig. 57). Banded shells number 333, constituting a class that will be called *cestata*, like its counterpart in *sinistrorsa*, although the details of the banding are somewhat different (plate 32, figs. 1 to 8). What may be regarded as the central type of this class is a shell with three clearly marked dark stripes on a lighter yellowish-brown background (plate 32, figs. 1 and 2); even in this the middle band is relatively narrower than in the typical *cestata* of *sinistrorsa*. The variates grade to darker forms in many cases, where the background becomes somewhat "filled up" by cross-strigations, but the bands never suffuse as they do in some of the subordinate color-forms to be described later. By the lightening of the middle band, save along its lower or "right" border (plate 32, figs. 3 and 5), a type is produced which leads to a still more modified pattern, in which the sutural and basal stripes have vanished on the body-

whorls, while the middle band has become a narrow and faint marking (plate 32, figs. 6 to 8). The spire, however, still displays distinct bands, so far as they are not covered by whorls added later.

The unstriped shells other than apex amount to 91 among the adults. Their class is still to be called *phæa* (plate 31, figs. 60 to 64), although much variation occurs, from deep brown (*solida*) specimens through *confluens* forms to others that are vaguely striped (fig. 64). Like the *phæa* class of Moaroa, etc., this group is plainly heterogeneous, yet it is not interruptedly differentiated into well-marked subdivisions, as it is in neighboring *sinistralis* associations.

TABLE 197.—*Partula otaheitana sinistralis*. Teohu Valley.

MEAN VALUE.									
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index. <sup>1</sup>
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
		<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>p. ct.</i>	
apex, sin. ....	35	17.4585 ± .0930	9.7400 ± .0490	55.7286 ± .1948	8.8243 ± .0517	6.6600 ± .0411	75.4143 ± .2237	50.6428 ± .1988	2.8572 ± .0950
cestata, sin. ...	331	17.2569 ± .0289	9.9665 ± .0149	57.6299 ± .0776	8.8946 ± .0167	6.7936 ± .0129	76.3368 ± .1009	51.4033 ± .0676	2.5976 ± .0267
phæa, sin. ....	91	17.2126 ± .0504	9.8319 ± .0285	57.0385 ± .1566	8.8451 ± .0270	6.6956 ± .0231	75.5329 ± .1727	51.2791 ± .1192	2.9121 ± .0487
All, sin. ....	457	17.2636 ± .0244	9.9222 ± .0129	57.3665 ± .0681	8.8794 ± .0138	6.7639 ± .0110	76.1061 ± .0834	51.3403 ± .0565	2.6797 ± .0232
STANDARD DEVIATION.									
apex, sin. ....	35	0.8161 ± .0658	0.4297 ± .0346	1.7086 ± .1377	0.4535 ± .0365	0.3603 ± .0291	1.9621 ± .1582	1.7426 ± .1406	0.8330 ± .0672
cestata, sin. ...	331	.7808 ± .0204	.4011 ± .0105	2.0923 ± .0549	.4509 ± .0118	.3484 ± .0091	2.7213 ± .0713	1.8228 ± .0478	.7230 ± .0189
phæa, sin. ....	91	.7137 ± .0356	.4024 ± .0201	2.2154 ± .1107	.3821 ± .0191	.3274 ± .0163	2.4425 ± .1221	1.6863 ± .0843	.6892 ± .0344
All, sin. ....	457	.7723 ± .0172	.4103 ± .0091	2.1583 ± .0481	.4390 ± .0097	.3487 ± .0078	2.6433 ± .0590	1.7918 ± .0399	.7379 ± .0164

<sup>1</sup>The numbers are, respectively, 35, 333, 91; 459.

TABLE 198.—*Partula otaheitana sinistralis*. Teohu Valley.

FECUNDITY.								
Series.	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.
1906. ....	409	320	78.2	472	129	601	1.88	1.47
1907. ....	49	41	83.7	65	35	100	2.44	2.04
DATA OF HEREDITY.								
					Young, sinistral, plain.	Young, sinistral, cestata.	Young, dextral, banded.	Total.
Adults:								
Plain. ....					27	16	1	44
cestata. ....					46	74	....	120
Total. ....					73	90	1	164

In statistical respects (table 197) the colony as a whole differs from the *sinistrorsa* association from Taharua, to degrees that are all the more remarkable in view of the proximity of that valley and in view of the connecting forests between it and Teohu. The three color-classes differ *inter se*, but rarely with statistical definiteness.

Fecundity (table 198) is low in the 1906 series, but fairly high in the small 1907 series; the reasons have been pointed out earlier at several points.

The assignment of embryonic young to color-classes equivalent to those of the adults is not possible throughout, because the unbanded young do not display the distinctive characters of the apex type until after they are born, judging by the adolescents studied. Grouping all of the plain individuals together (table 198), the numbers of cestata among the offspring are fewer than among the gravid adults, leading to the conclusion that the developemnt of stripes, like the appearance of the darkened spire in apex, is deferred.

A single *dextral* banded shell was borne by a plain *sinistral* adult! On the basis of the adult and adolescent series, the colony would seem to be entirely devoid of the dextral character in its heritage; the value of the embryonic snails is nowhere clearer than in such a case as this.

#### PAPEITI VALLEY.

Despite the close geographical relationship between Papeiti and its sister valley Temarua (a matter discussed earlier), the *sinistralis* colonies are intrinsically as different as though the two localities were entirely separate.

TABLE 199.—*Partula otaheitana sinistralis*. Papeiti Valley.

MEAN VALUE.									
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index. <sup>1</sup>
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
apex .....	8	<i>mm.</i> 16.7375±.1515	<i>mm.</i> 9.2500±.0782	<i>p. ct.</i> 55.1250±.5324	<i>mm.</i> 8.6250±.1142	<i>mm.</i> 6.5000±.0337	<i>p. ct.</i> 75.7500±.6281	<i>p. ct.</i> 51.1250±.3759	3.0000±.1192
phæa striata .....	142	16.5479±.0438	9.3268±.0245	56.3028±.1306	8.5366±.0256	6.5366±.0213	76.5352±.1529	51.4366±.0994	2.8733±.0328
phæa confluens .....	116	16.7517±.0424	9.4362±.0229	56.3017±.1532	8.6362±.0261	6.5793±.0216	76.2155±.1836	51.3103±.1194	2.9483±.0375
Unbanded classes	266	16.6425±.0326	9.3722±.0168	56.2664±.0982	8.5827±.0182	6.5541±.0158	76.3722±.1162	51.3722±.0753	2.9098±.0243
cestata .....	208	16.7014±.0340	9.2993±.0202	55.5096±.1054	8.5240±.0189	6.5240±.0172	76.3076±.1330	50.9760±.0774	2.8708±.0291
All .....	474	16.6684±.0236	9.3359±.0130	55.9346±.0729	8.5506±.0129	6.5409±.0112	76.3439±.0794	51.1983±.0545	2.8926±.0187
STANDARD DEVIATION.									
apex .....	8	0.6353±.1071	0.3279±.0553	2.2326±.3765	0.4789±.0807	0.1414±.0238	2.6339±.4441	1.5762±.2658	0.5000±.0843
phæa striata .....	142	.7739±.0310	.4328±.0173	2.3081±.0923	.4519±.0181	.3758±.0151	2.7021±.1081	1.7571±.0703	.5797±.0232
phæa confluens .....	116	.7993±.0353	.3654±.0162	2.4468±.1083	.4165±.0184	.3453±.0153	2.9326±.1298	1.9069±.0844	.5995±.0265
Unbanded classes	266	.7879±.0230	.4058±.0119	2.3759±.0694	.4405±.0129	.3813±.0112	2.8108±.0822	1.8206±.0532	.5876±.0172
cestata .....	208	.7265±.0240	.4315±.0143	2.2532±.0745	.4043±.0133	.3674±.0122	2.8440±.0940	1.6552±.0547	.6241±.0206
All .....	474	.7622±.0167	.4194±.0092	2.3535±.0515	.4159±.0091	.3626±.0079	2.5629±.0561	1.7609±.0385	.6044±.0132

<sup>1</sup>The numbers are: cestata, 209; total, 475.

The color-form apex is represented by 8 adults, or 1.7 per cent. The cestata shells differ from those of Teohu in having the bands sharply outlined (plate 32, figs. 14, 15); none of them is like the intermediate form of Teohu shown in plate 32, figure 5, although in some cases the sutural band fades out along the line of articulation of successive whorls (plate 32, fig. 15). The most notable feature of the whole colony is the division of the phæa class into confluens (plate 32, figs. 12 and 13,

unusual types) and the one called *striata*, which is characterized by sharply defined dark strigations upon a lighter background (plate 32, figs. 9 to 11). The latter class was suggested by certain of the bandless shells of the *Tenaire sinistrorsa* colony.

Statistically (table 199) the shells are collectively different from those of Teohu, being even more abbreviated but not more tightly coiled. The apex class resembles the associated groups of the same valley more than the same class of Teohu.

Taken in March 1906, the fecundity (table 200) of the colony is naturally low; the recent resumption of breeding activity is the cause.

In the figures for heredity (table 200) the unbanded classes are united for comparison with *cestata*. The number of banded offspring is smaller than the number of gravid adults, which indicates a late manifestation of the characteristic bands.

TABLE 200.—*Partula otaheitana sinistralis*. Papeiti Valley.

FECUNDITY.									HEREDITY OF PATTERN.		
Series.	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.	Young, unbanded.	Young, cestata.	Total.
Unbanded classes.	265	198	74.7	259	70	329	1.66	1.24	63	7	70
cestata. ....	209	150	71.8	214	40	254	1.69	1.21	20	20	40
All. ....	474	348	73.4	473	110	583	1.67	1.23	83	27	110

## TEMARUA VALLEY.

In making the collections here during the summer of 1908, all the snails were taken in the middle and upper part of the valley so as to secure a series from a territory that was well cut off from the Papeiti region. Out of 563 adults, only one was an apex shell, although two similar specimens of partial growth were found; none of them showed any indication of decortication. The *phæa* class is not differentiated into *striata* and *confluens* subdivisions, but is continuously variable, although scarcely any shells exhibit the sharply defined strigations of so many Papeiti individuals; of the specimens illustrated (plate 32, figs. 16 to 19), that of figure 16 is unusual in having a clear revolving area below the suture, while those of figures 17 to 19 are aberrant in particulars of size or form.

The *cestata* class falls into two divisions, which merge into one another through transitional individuals; in one of these the bands are clearly and boldly marked, while in the other (plate 32, fig. 20) heavy dark strigations partially obscure the stripes. Two dark *dextral* shells of this color-type were discovered (plate 32, figs. 21 and 22).

Statistically (table 201) this colony proves to be much like that of Papeiti. The color-classes differ very little from one another. The two *dextral* specimens are quite unlike, which would point to their independent origin by mutation from *sinistral* parents, rather than to their genetic relationship.

The fertility of the colony is high (table 202) as compared with that of Papeiti, on account of the seasonal difference in the time of collection. The *cestata* class displays a somewhat higher rate of productivity, but the difference is not very great.



Among the young (table 202) the *banded* pattern is exhibited in a very small number of cases as compared with its prevalence in the adult series. Without question the distinctive bands develop only after the birth of the young snails.

TABLE 201.—*Partula otaheitana sinistralis*. Temarua Valley.

MEAN VALUE.									
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
Unbanded, sin..	195	<i>mm.</i> 16.8992±.0365	<i>mm.</i> 9.5749±.0199	<i>p. ct.</i> 56.5872±.1080	<i>mm.</i> 8.7913±.0208	<i>mm.</i> 6.7287±.0168	<i>p. ct.</i> 76.5205±.1241	<i>p. ct.</i> 51.8949±.0797	3.1224±.0294
cestata, sin.....	364	16.8228±.0254	9.5587±.0135	56.7582±.0772	8.7247±.0135	6.6874±.0114	76.5467±.0865	51.7720±.0584	3.0301±.0183
All, sin.....	559	16.8495±.0207	9.5644±.0112	56.6986±.0629	8.7480±.0114	6.7018±.0095	76.5376±.0710	51.8148±.0471	3.0624±.0158
Specimen 1, dex.	1	16.55	9.90	60.5	8.30	6.70	79.5	50.5	3.
Specimen 2, dex.	1	18.95	10.70	56.5	9.90	7.30	73.5	52.5	4.
STANDARD DEVIATION.									
Unbanded, sin..	195	0.7561±.0258	0.4130±.0141	2.2366±.0764	0.4307±.0147	0.3477±.0119	2.5699±.0877	1.6495±.0564	0.6105±.0208
cestata, sin.....	364	.7181±.0179	.3834±.0095	2.1849±.0546	.3828±.0095	.3233±.0081	2.4473±.0611	1.6509±.0413	.5199±.0129
All, sin.....	559	.7257±.0146	.3940±.0079	2.2046±.0445	.4014±.0081	.3327±.0067	2.4908±.0502	1.6515±.0333	.5550±.0112

TABLE 202.—*Partula otaheitana sinistralis*. Temarua Valley.

FECUNDITY.									HEREDITY OF PATTERN.		
Series.	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.	Young, unbanded.	Young, cestata.	Total.
Unbanded, sin...	161	142	88.2	179	94	273	1.92	1.69	90	4	94
cestata, sin.....	286	245	85.7	326	182	508	2.07	1.77	125	57	182
All, sin.....	447	387	86.5	505	276	781	2.04	1.74	215	61	276

## VAIPOO, TEARATAPU, AND OPIRIROA VALLEYS.

The western boundary of Temarua Valley is the precipitous face of the high mountain sector that intervenes between Temarua and Orofere valleys (plates 6*b* and 13). The ridge ends west of the former in dry boundaries without trees along their seaward faces, but passing westward, the slope recedes and obtains a degree of moisture that allows a growth of small forest (plate 16*a*). Vaipoo Valley is little more than a shallow depression of the coastward slopes; its stream is very small, excepting after a copious rainfall. Tearatapu is about half a mile to the west of Vaipoo and partakes of the same character, although it is deeper and it extends higher up on the mountain side. Opiriroa is still deeper and longer in radial extent, and its valley bottom is more like that of an element like Teohu.

A few snails were taken in Vaipoo and Tearatapu in the course of a close study of the area of vegetation along the ends of the mountain ridges, prosecuted mainly for the purpose of determining whether the habitable areas of radial valleys were connected between their mouths; this was found to be the case.

The material from these two localities, as well as that from Opiriroa, has not the value of a long series taken in a valley like Moaroa, but it is interesting on account of its demonstration that local variations in size, etc., can be found in series taken from places very near one another. In another way it is important, inasmuch as the banded class includes two somewhat novel kinds of color-variants, which become even more numerous farther west; hence the area in which the newer forms occur is transitional from that of previously described *sinistralis* associations.

As indicated in table 196, apex is absent from all three series. The unbanded shells are almost all true confluens (plate 32, figs. 23 and 24), although some vaguely strigated individuals occur, which, nevertheless, fall short of the distinctive striata type. The banded shells fall into three subdivisions, as follows: (a) basal band light, sutural band and median band distinct up to the last whorl, when the latter fades out (plate 32, figs. 25 and 26); (b) all three bands continued throughout the basal whorl (plate 32, figs. 27 and 28); (c) with suffusion of the bands over the last whorl (plate 32, figs. 29 to 31). The spires of all three types are almost exactly the same in appearance. It is true that among *sinistrorsa* shells we have seen some with the great amount of suffusion on the last whorl, but this is the first area where a distinct subclass with this character can be recognized.

TABLE 203.—*Partula otaheitanensis sinistralis*. Vaipoo, Tearatapu, and Opiriroa Valleys.

MEAN VALUE.									
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
Vaipoo, unbanded . . . . .	12	mm. 17.2750 ± .1677	mm. 9.6167 ± .1023	p. ct. 55.7500 ± .3476	mm. 8.8667 ± .1005	mm. 6.6834 ± .0538	p. ct. 75.3334 ± .4193	p. ct. 51.1666 ± .3756	2.8462 ± .1920
	49	16.9480 ± .0669	9.6796 ± .0342	57.0918 ± .2244	8.8551 ± .0366	6.7245 ± .0320	75.8469 ± .2637	52.2349 ± .1637	2.9184 ± .0950
Vaipoo, all . . . . .	61	17.0123 ± .0641	9.6672 ± .0341	56.8279 ± .1982	8.8574 ± .0354	6.7164 ± .0278	75.7459 ± .2280	52.0246 ± .1553	2.9033 ± .0852
Tearatapu, unbanded . . . . .	15	16.7100 ± .1060	9.7000 ± .0623	58.0334 ± .2688	8.9133 ± .0799	6.8467 ± .0642	76.7000 ± .4460	53.3000 ± .2928	3.0666 ± .1184
	15	16.6900 ± .1916	9.7133 ± .0903	58.3667 ± .4490	8.8467 ± .1196	6.8467 ± .0885	77.5666 ± .2877	53.0334 ± .3357	2.8000 ± .1303
Tearatapu, all . . . . .	30	16.7000 ± .1096	9.7067 ± .0530	58.2000 ± .2625	8.8800 ± .0720	6.8467 ± .0547	77.1333 ± .2707	53.1667 ± .2233	2.9333 ± .0895
Opiriroa, unbanded . . . . .	40	18.1850 ± .0988	9.8550 ± .0388	54.0000 ± .2336	9.1850 ± .0522	6.9800 ± .0412	75.6250 ± .3009	50.4000 ± .1407	3.1750 ± .0787
	112	18.2214 ± .0442	9.9982 ± .0241	54.7857 ± .1279	9.2590 ± .0253	7.0715 ± .0200	76.3214 ± .1610	50.7143 ± .1023	2.8929 ± .0453
Opiriroa, all . . . . .	162	18.2118 ± .0417	9.9605 ± .0208	54.5789 ± .1141	9.2395 ± .0232	7.0474 ± .0184	76.1382 ± .1436	50.6316 ± .0843	2.9671 ± .0399
STANDARD DEVIATION.									
Vaipoo, unbanded . . . . .	12	0.8613 ± .1186	0.5257 ± .0723	1.7853 ± .2458	0.5163 ± .0711	0.2764 ± .0380	2.1538 ± .2965	1.9293 ± .2656	1.0263 ± .1358
	49	.6947 ± .0473	.3551 ± .0242	2.3292 ± .1587	.3796 ± .0259	.3323 ± .0226	2.7371 ± .1865	1.6994 ± .1157	.9864 ± .0672
Vaipoo, all . . . . .	61	.7419 ± .0453	.3953 ± .0241	2.2955 ± .1401	.4099 ± .0250	.3224 ± .0196	2.6405 ± .1612	1.7980 ± .1098	.9953 ± .0602
Tearatapu, unbanded . . . . .	15	.6086 ± .0749	.3578 ± .0440	1.5434 ± .1901	.4588 ± .0565	.3686 ± .0454	2.5612 ± .3154	1.6812 ± .2070	.6798 ± .0837
	15	1.1002 ± .1355	.5188 ± .0638	2.5785 ± .3175	.6869 ± .0846	.5084 ± .0626	1.6519 ± .2034	1.9276 ± .2374	.7483 ± .0921
Tearatapu, all . . . . .	30	.8905 ± .0775	.4468 ± .0375	2.1315 ± .1856	.5850 ± .0509	.4440 ± .0387	2.1982 ± .1914	1.8135 ± .1579	.7272 ± .0633
Opiriroa, unbanded . . . . .	40	.9269 ± .0699	.3646 ± .0274	2.1909 ± .1652	.4896 ± .0369	.3868 ± .0291	2.8212 ± .2128	1.3191 ± .0995	.7378 ± .0556
	112	.6940 ± .0312	.3789 ± .0170	2.0063 ± .0904	.3974 ± .0179	.3138 ± .0141	2.5256 ± .1138	1.6059 ± .0723	.7116 ± .0320
Opiriroa, all . . . . .	162	.7624 ± .0295	.3804 ± .0147	2.0854 ± .0807	.4250 ± .0164	.3368 ± .0130	2.6246 ± .1015	1.5419 ± .0596	.7292 ± .0282

The statistical description of the three associations (table 203) is valuable, as it defines the characters of shells that are geographically intermediate between the Tamarua colony and the fuller series of *sinistralis* in westward valleys. The large size of the Opiriroa shells is the most notable point of the inter-valley comparison. As a class, *cestata* is sometimes smaller and sometimes larger than its associated group in the same valley, but the two divisions of any one colony are far more similar than the *cestata* classes of two contiguous valleys, or two *confluens* groups of different localities; the figures for the shell proportions illustrate this point most clearly.

In fertility (table 204) the figures are all somewhat below the average for the summer season. The snails were not found in abundance, and hence the rate of productivity would naturally be less than in a numerous and more compact association.

TABLE 204.—*Partula otaheitana sinistralis*. Vaipoo, Tearatapu, and Opiriroa Valleys. Fecundity.

Series.	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.
Vaipoo, unbanded.....	13	7	53.8	5	3	8	1.14	0.61
banded.....	49	36	73.5	43	29	72	2.00	1.47
All.....	62	43	69.3	48	32	80	1.86	1.29
Tearatapu, unbanded...	15	15	100.0	14	13	27	1.80	1.80
banded.....	15	13	86.6	15	9	24	1.85	1.60
All.....	30	28	93.3	29	22	51	1.82	1.70
Opiriroa, unbanded.....	40	29	72.5	42	23	75	2.58	1.87
banded.....	112	84	75.0	110	53	163	1.94	1.45
All.....	152	113	74.3	152	76	228	2.02	1.50

The data of heredity (table 205) prove the genetic interrelationships of the contrasted color-groups. The figures give the facts as observed, but undoubtedly the preponderance of unbanded young in Opiriroa, for example, means that the bands develop later, and not that a change in the constitution of the colony is coming about. In Tearatapu the bands appear early.

TABLE 205.—*Partula otaheitana sinistralis*. Data of heredity.

	Vaipoo Valley.			Tearatapu Valley.			Opiriroa Valley.		
	Young, plain.	Young, banded.	Total.	Young, plain.	Young, banded.	Total.	Young, plain.	Young, banded.	Total.
Adults:									
Plain.....	0	3	3	9	4	13	23	0	23
Banded.....	10	19	29	2	7	9	48	5	53
Total.....	10	22	32	11	11	22	71	5	76

#### OTUNA VALLEY.

The *sinistralis* series taken in Otuna during the wet season of 1906 comprises 346 adults and 87 adolescents. With this material it is profitable to undertake a more detailed analysis of the color-types. As before, shells of the *cestata* class out-

number the plain ones; they fall into the three subordinate divisions distinguished and illustrated in the Opiriroa colony. The unbanded shells are dark, on the whole, segregating into *phæa solida* of the original kind, and *phæa confluens* (plate 32, figs. 32 to 34); some of the latter approach but do not attain the *striata* form of coloration.

Statistically (table 206) the shells of this colony prove to be larger and narrower than those of the eastward associations; *solida* and *confluens* differ little in length, but shells of the latter subclass are narrower and more slender than those of the former. In the comparison of the subordinate *cestata* groups, it appears that *in all three proportionate measures* the figure increases with the intensity of coloration; the differences, it is true, are not always statistically significant, but the changes are consistent nevertheless.

TABLE 206.—*Partula otaheitana sinistralis*. Otuna Valley.

MEAN VALUE.									
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
<i>phæa confluens</i> ..	48	<i>mm.</i> 18.4812±.0727	<i>mm.</i> 10.2125±.0399	<i>p. ct.</i> 55.1875±.1876	<i>mm.</i> 9.4708±.0363	<i>mm.</i> 7.2250±.0334	<i>p. ct.</i> 76.2708±.2188	<i>p. ct.</i> 51.1458±.1858	2.8958±.0848
	62	18.5193±.0722	10.1323±.0354	54.6452±.1813	9.4774±.0362	7.1806±.0308	75.6290±.2189	51.1935±.1302	3.0161±.0761
<i>cestata</i> (a).....	25	18.8060±.1110	10.3000±.0539	54.7400±.3523	9.6280±.0544	7.2440±.0497	75.4200±.4018	51.0600±.1752	2.8462±.1082
	111	18.4797±.0579	10.2604±.0256	55.4640±.1505	9.5450±.0294	7.2477±.0240	75.9594±.1836	51.4639±.1242	2.8919±.0449
	100	18.6320±.0458	10.4540±.0313	56.0500±.1422	9.6420±.0314	7.3340±.0252	76.0200±.1670	51.6000±.1295	2.9300±.0470
<i>phæa</i> .....	110	18.5027±.0516	10.1673±.0198	54.8818±.1292	9.4745±.0258	7.2000±.0227	75.9090±.1597	51.1727±.1094	2.9637±.0568
<i>cestata</i> .....	236	18.5788±.0357	10.3466±.0192	55.6356±.1017	9.5949±.0201	7.2839±.0165	75.9280±.1196	51.4788±.0825	2.9030±.0313
All .....	346	18.5546±.0294	10.2896±.0159	55.3960±.0821	9.5566±.0161	7.2572±.0135	75.9220±.0962	51.3815±.0664	2.9222±.0279
STANDARD DEVIATION.									
<i>phæa confluens</i> ..	48	0.7472±.0514	0.4101±.0282	1.9274±.1326	0.3731±.0257	0.3431±.0236	2.2476±.1547	1.9093±.1314	0.8718±.0599
	62	.8427±.0510	.4133±.0250	2.1163±.1282	.4223±.0256	.3600±.0218	2.5557±.1548	1.5196±.0921	.8883±.0538
<i>cestata</i> (a).....	25	.8232±.0785	.4000±.0381	2.6119±.2491	.4035±.0385	.3688±.0351	2.9788±.2841	1.2986±.1239	.8177±.0765
	111	.9046±.0407	.3998±.0181	2.3516±.1064	.4601±.0208	.3754±.0170	2.8688±.1298	1.9402±.0878	.7020±.0317
	100	.6799±.0324	.4646±.0221	2.1089±.1005	.4651±.0222	.3742±.0178	2.4757±.1181	1.9209±.0916	.6965±.0332
<i>phæa</i> .....	110	.8026±.0365	.3084±.0140	2.0089±.0913	.4019±.0182	.3534±.0160	2.4837±.1129	1.7009±.0773	.8834±.0401
<i>cestata</i> .....	236	.8148±.0252	.4381±.0136	2.3194±.0719	.4593±.0142	.3767±.0117	2.7275±.0846	1.8809±.0583	.7138±.0221
All .....	346	.8117±.0208	.4390±.0112	2.2657±.0580	.4454±.0114	.3715±.0095	2.6525±.0680	1.8311±.0469	.7721±.0197

As the time of collection fell within the wet season, the figures for fecundity (table 207) are unexpectedly high. The two color groups are almost exactly alike.

The noteworthy feature as to heredity is the small number of banded young. The distinctive bands must make their appearance only after the birth of the young snails destined to be *cestata* as adults. In this connection it may be added that shells of subdivision (c) are relatively scarce among the adolescent population, as would be expected from the fact that their distinguishing characters appear only in the coloration of the body whorl.

TABLE 207.—*Partula otaheitana sinistralis*. Otuna Valley.

FECUNDITY.								
Series.	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.
phæa .....	108	74	68.5	107	58	165	2.23	1.53
cestata .....	237	166	70.0	251	123	374	2.25	1.58
All .....	345	240	69.5	358	181	539	2.24	1.56

HEREDITY.			
Adults.	Young, plain.	Young, banded.	Total.
phæa confluens .....	20	2	22
solida .....	33	3	36
cestata (a) .....	8	3	11
(b) .....	39	22	61
(c) .....	44	7	51
Total .....	144	37	181

## MARUIA VALLEY.

With this valley we enter a series of three consecutive localities where dextral representatives of *sinistralis* occur in substantial numbers. Here the reversed individuals amount to 94, while the directly coiled snails number 25. Both color-classes—phæa and cestata—occur in each mode of coil (plate 32, figs. 35 to 41), but the cestata shells are distinctly banded for the most part; the suffused coloration shown by figures 36, 37, and 41 is somewhat infrequent. The shells of figures 36

TABLE 208.—*Partula otaheitana sinistralis*. Maruia Valley.

MEAN VALUE.									
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index. <sup>1</sup>
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
phæa, sin ...	43	mm. 18.1543 ± .0740	mm. 10.3186 ± .0351	p. ct. 56.7791 ± .2276	mm. 9.4349 ± .0434	mm. 7.2581 ± .0354	p. ct. 76.7791 ± .2720	p. ct. 51.8488 ± .1841	1.7675 ± .1060
	60	17.9250 ± .0618	10.2467 ± .0310	57.2000 ± .1828	9.2767 ± .0379	7.1633 ± .0292	77.3000 ± .2497	51.6333 ± .1708	1.4423 ± .0646
All, sin. ....	103	18.0209 ± .0483	10.2767 ± .0234	57.0244 ± .1434	9.3427 ± .0290	7.2029 ± .0227	77.0825 ± .1853	51.7233 ± .1259	1.5895 ± .0606
phæa, dex ...	8	17.9750 ± .1549	10.2250 ± .0581	56.6250 ± .4373	9.3250 ± .0802	7.0250 ± .0752	74.7500 ± .5299	51.6250 ± .2511	1.8750 ± .2210
	17	18.3676 ± .1135	10.6417 ± .0534	57.9117 ± .3493	9.6294 ± .0582	7.3352 ± .0452	76.2647 ± .3100	52.3823 ± .3267	1.4118 ± .1136
All, dex. ....	25	18.2420 ± .0950	10.5080 ± .0485	57.5000 ± .2778	9.5320 ± .0510	7.2360 ± .0436	75.78 ± .2868	52.1400 ± .2379	1.5600 ± .1084
STANDARD DEVIATION.									
phæa, sin ...	43	0.7200 ± .0523	0.3418 ± .0248	2.2131 ± .1609	0.4219 ± .0307	0.3439 ± .0250	2.6442 ± .1923	1.7899 ± .1302	1.0307 ± .0749
	60	.7098 ± .0437	.3556 ± .0219	2.1000 ± .1292	.4352 ± .0268	.3356 ± .0206	2.8682 ± .1765	1.9619 ± .1208	.6909 ± .0457
All, sin. ....	103	.7271 ± .0341	.3517 ± .0165	2.1580 ± .1014	.4368 ± .0205	.3423 ± .0160	2.7887 ± .1310	1.8949 ± .0890	.8765 ± .0428
phæa, dex ...	8	.6495 ± .1095	.2437 ± .0411	1.8337 ± .3092	.3382 ± .0567	.3152 ± .0532	2.2220 ± .3747	1.0532 ± .1775	.9270 ± .1563
	17	.6939 ± .0802	.3267 ± .0377	2.1351 ± .2470	.3560 ± .0411	.2765 ± .0319	1.8952 ± .2192	1.9669 ± .2310	.6943 ± .0803
All, dex. ....	25	.7042 ± .0672	.3599 ± .0343	2.0591 ± .1964	.3781 ± .0360	.3236 ± .0308	2.1264 ± .2028	1.7636 ± .1682	.8039 ± .0766

<sup>1</sup>The numbers in the reversed groups are 43, 52; 95.

and 37 are aberrant in the colors of the subsutural region. When the two color-classes are compared statistically (table 208) the remarkable fact appears that their relations in the case of sinistral shells are just the opposite of those displayed by the two dextral color-classes, so far as the differences in absolute measures are concerned. In both modes of coil, however, the cestata shells are broader, and their apertures are relatively wider. The dextral and sinistral groups differ from one another in interesting ways. In all sections the columellar tooth is very poorly developed.

TABLE 209.—*Partula otaheitana sinistralis*. Maruia Valley. Fecundity.

Series.	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.
Plain, sin.....	42	36	85.7	53	44	97	2.69	2.31
Banded, sin.....	61	46	75.4	75	44	119	2.58	1.95
All, sin.....	103	82	79.6	128	88	216	2.63	2.09
Banded, dex.....	1	1	....	1	2	3	3.00	3.00

TABLE 210.—*Partula otaheitana sinistralis*. Maruia Valley.

FULL DATA OF HEREDITY.					
	Young, sin.		Young, dex.		Total.
	Plain.	Banded.	Plain.	Banded.	
Adults:					
Plain, sin.....	29	5	7	3	44
Banded, sin.....	19	21	1	3	44
Plain, dex.....	..	..	..	..	0
Banded, dex.....	..	..	..	2	2
Total.....	48	26	8	8	90

SUMMARY. HEREDITY OF PATTERN.				SUMMARY. HEREDITY OF COIL.			
	Plain young, sin. and dex.	Banded young, sin. and dex.	Total.		Young, sin.	Young, dex.	Total.
Adults:				Adults:			
Plain, sin. and dex....	36	8	44	Sin.....	74	14	88
Banded, sin. and dex..	20	26	46	Dex.....	0	2	2
Total.....	56	34	90	Total.....	74	16	90

Fecundity is high throughout the series (table 209). Only one record of a dextral snail is given, because the adults of this kind were kept alive for transport home; hence the table of heredity (table 210) is somewhat misleading on account of the lack of records from dextral adults. The positive results are (1) that sinistral parents of both color-types produce young of all four kinds; (2) that the plain young are fewer relatively in their generation than the unbanded adults in theirs; (3) that the group of sinistral young is relatively smaller, but this last result is not to be taken as final for the above-stated reason.

## TEREEHIA VALLEY.

Tereehia is the largest valley to the west of Temarua before the southwest corner of the island is reached. Undoubtedly it is one of the "two large valleys" referred to by Garrett in his description of the distribution of *sinistralis*; therefore its colony is of much historical interest in addition to its intrinsic value.

The collection comprises 130 adult specimens, of which 70 were sinistral; 12 of these display the *phæa confluens* form of coloration, while the rest are banded, falling into the three subordinate types described for Maruia. The 60 dextral shells are all *cestata* and they also resolve themselves into the three subordinate color-phases, but the group whose members show only faint bands includes a few with unusually heavy cross strigations (plate 32, figs. 42 and 43) so that they closely resemble *striata* shells of the unbanded class. The group of *cestata* (*c*) with suffusion of color over the terminal whorl, is sharply separated from subclass (*b*), which has very distinct bands.

TABLE 211.—*Partula otaheitana sinistralis*, Tereehia Valley.

MEAN VALUE.									
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
Unbanded, sin.	12	<i>mm.</i> 17.6250 ± .1614	<i>mm.</i> 9.8834 ± .0753	<i>p. ct.</i> 55.9166 ± .3767	<i>mm.</i> 9.0000 ± .0605	<i>mm.</i> 6.8334 ± .0659	<i>p. ct.</i> 76.0000 ± .5536	<i>p. ct.</i> 50.9166 ± .4865	1.6667 ± .1214
Banded, sin. . . .	57	17.6079 ± .0762	9.8579 ± .0360	55.8859 ± .1999	8.9597 ± .0362	6.7702 ± .0348	75.5175 ± .2422	50.8333 ± .1546	1.6207 ± .0867
All' sin. . . . .	69	17.6109 ± .0688	9.8623 ± .0326	55.8913 ± .1773	8.9667 ± .0317	6.7812 ± .0311	75.6014 ± .2225	50.8478 ± .1532	1.6286 ± .0748
Banded, dex. . . .	60	18.2650 ± .0648	10.1433 ± .0335	55.5333 ± .1571	9.1833 ± .0351	6.9600 ± .0276	75.6166 ± .1941	50.3334 ± .1378	1.9500 ± .0959
STANDARD DEVIATION.									
Unbanded, sin.	12	0.8288 ± .1141	0.3870 ± .0532	1.9347 ± .2664	0.3109 ± .0428	0.3385 ± .0466	2.8431 ± .3914	2.4986 ± .3440	0.6236 ± .0858
Banded, sin. . . .	57	.8528 ± .0539	.4030 ± .0254	2.2381 ± .1413	.4052 ± .0256	.3902 ± .0246	2.7112 ± .1712	1.7303 ± .1093	.9796 ± .0613
All, sin. . . . .	69	.8479 ± .0486	.4016 ± .0230	2.1838 ± .1254	.3907 ± .0224	.3827 ± .0220	2.7407 ± .1573	1.8868 ± .1083	.9285 ± .0529
Banded, dex. . . .	60	.7445 ± .0458	.3848 ± .0237	1.8043 ± .1111	.4037 ± .0248	.3168 ± .0195	2.2293 ± .1372	1.5829 ± .0974	1.1019 ± .0678

The important features of the quantitative descriptive (table 211) are (1) the substantial similarity throughout of the two sinistral color-classes, and (2) the larger size in all absolute measures of the dextral *cestata* class. The pillar tooth is weakly developed, which is interesting in view of Garrett's statement that *sinistralis* is always dentated.

TABLE 212.—*Partula otaheitana sinistralis*. Tereehia Valley. Fecundity.

Series.	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.
Unbanded, sin. . . . .	12	6	50.0	6	2	8	1.33	0.75
Banded, sin. . . . .	58	26	44.8	29	10	39	1.50	0.67
Banded, dex. . . . .	60	34	56.6	28	29	57	1.67	0.95

Fecundity (table 212) is low, and hence there are scanty data for the determination of the facts of heredity (table 213). The latter are very interesting, however, because in summary the numbers of sinistral and dextral young are almost exactly the same as those for gravid parents; the appearance of bands is apparently delayed in development, for plain young preponderate in all arrays.

TABLE 213.—*Partula otaheitana sinistralis*. Tereehia Valley.

FULL DATA OF HEREDITY.						SUMMARY.			
	Young, sin.		Young, dex.		Total.		Young, sin.	Young, dex.	Total.
	Unbanded.	Banded.	Unbanded.	Banded.					
Adults:						Adults:			
Sin., unbanded.....	1	..	1	..	2	Sin. ....	8	4	12
banded.....	7	..	2	1	10	Dex. ....	5	24	29
Dex., banded.....	4	1	18	6	29	Total. ....	13	28	41
Total.....	12	1	21	7	41				

## TIAMAO VALLEY.

Tiamao is the third and last area which is inhabited by any considerable numbers of dextral *sinistralis* in addition to the more characteristic reversed kind. The valley is smaller than Tereehia, but it is thickly populated by *Partula*.

Of 177 adults (54 per cent) that are sinistral, 8 only are devoid of bands, and display the *phaea confluens* coloration, although in one or two there is some degree of approach to the *striata* subtype. The contrasted *cestata* shells fall into the three subclasses established earlier, viz (a) faint bands on body-whorl (plate 32, figs. 44 and 45), (b) distinctly banded throughout (plate 32, figs. 46 and 47), (c) suffused color on the last whorl (plate 32, figs. 48 and 49); the numbers are 29, 68, and 72, respectively (about 17 per cent, 40 per cent, and 42 per cent).

Among the dextral and unbanded shells is one that is virtually an apex in ground-color, but it lacks the dark spire of typical apex in other *sinistralis* colonies (Teohu) and in *sinistrorsa* (plate 32, fig. 50). The remaining plain shells belong to the *phaea* group (plate 32, figs. 51 and 52), without definite segregation into *striata* and *confluens*. Banded dextral shells of all three subordinate kinds occur (plate 32, figs. 53 to 57) as follows: (a) 19, (b) 57, and (c) 63 (13, 41, and 45 per cent, respectively).

The statistical analysis of this colony is carried out in further detail than heretofore, because the dextral series is more like the sinistral part of the population in make-up. The figures are given in table 214. The major points are: (1) the sinistral and dextral groups are virtually the same in all characters; (2) the unbanded group differs from *cestata* in the same way in both coils as far as the measures of the shell as a whole are concerned, but in different ways in other characters, without any regularity; (3) the three subordinate *cestata* groups differ *inter se* more often in absolute dimensions than in the proportionate measures. In brief, the interrelationships of all recognizable groups are so close as to render the colony as a whole a somewhat compact one in genetic constitution.



TABLE 214.—*Partula otaheitana sinistralis*. *Tiamao Valley*.

MEAN VALUE.									
Series.	No.	Shell.			Aperture.			Length aper- ture ÷ length shell, propor- tions.	Tooth, index. <sup>1</sup>
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
		<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>p. ct.</i>	
cestata (a), sin..	29	17.8017 ± .1012	10.1345 ± .0336	56.9138 ± .2916	9.2931 ± .0458	6.9414 ± .0318	74.3621 ± .2749	52.1897 ± .1922	1.2414 ± .0629
(b), sin..	67	17.8978 ± .0611	10.2045 ± .0311	56.9030 ± .1846	9.2493 ± .0357	6.9717 ± .0329	75.2761 ± .2334	51.6343 ± .1519	1.3667 ± .0484
(c), sin..	72	17.7833 ± .0620	10.1195 ± .0272	56.8472 ± .1602	9.1695 ± .0356	6.8611 ± .0248	74.8750 ± .2011	51.3889 ± .1542	1.6250 ± .0613
cestata, all, sin..	168	17.8322 ± .0401	10.1560 ± .0181	56.8809 ± .1125	9.2226 ± .0224	6.9191 ± .0179	74.9465 ± .1365	51.6250 ± .0987	1.4556 ± .0352
Plain, sin.....	8	17.4500 ± .1186	10.0500 ± .0976	57.3750 ± .4834	9.1000 ± .0754	6.9250 ± .0556	76.0000 ± .2566	51.8750 ± .4288	1.5000 ± .1686
All, sin.....	176	17.8148 ± .0389	10.1511 ± .0178	56.9034 ± .1097	9.2170 ± .0217	6.9193 ± .0173	74.9943 ± .1313	51.6364 ± .0944	1.4567 ± .0345
cestata (a), dex.	19	17.5763 ± .1358	10.1000 ± .0550	57.3421 ± .3146	9.0474 ± .0626	6.8053 ± .0453	75.1842 ± .3332	51.4474 ± .2990	1.5790 ± .1358
(b), dex.	56	17.8036 ± .0741	10.1786 ± .0415	57.1071 ± .1734	9.1875 ± .0400	6.7893 ± .0328	73.8393 ± .1860	51.3214 ± .1476	1.4737 ± .0606
(c), dex.	63	17.9643 ± .0657	10.2206 ± .0315	56.7381 ± .1925	9.2651 ± .0370	6.9127 ± .0258	74.5794 ± .1758	51.4206 ± .1583	1.7937 ± .0789
cestata, all, dex.	138	17.8457 ± .0470	10.1870 ± .0230	56.9700 ± .1213	9.1970 ± .0252	6.8478 ± .0192	74.3623 ± .1371	51.3840 ± .1025	1.6331 ± .0481
Plain, dex.....	10	17.7900 ± .1480	10.1200 ± .0445	56.9000 ± .3465	9.3200 ± .0699	6.8600 ± .0418	73.3000 ± .3910	52.3000 ± .5029	1.7000 ± .1366
All, dex.....	148	17.8432 ± .0450	10.1824 ± .0222	56.9662 ± .1155	9.2054 ± .0240	6.8487 ± .0181	74.3176 ± .1308	51.4459 ± .1023	1.6376 ± .0458
STANDARD DEVIATION.									
cestata (a), sin..	29	0.8075 ± .0715	0.2682 ± .0237	2.3268 ± .2062	0.3657 ± .0324	0.2539 ± .0225	2.1929 ± .1944	1.5332 ± .1356	0.5021 ± .0445
(b), sin..	67	.7410 ± .0432	.3775 ± .0220	2.2398 ± .1305	.4334 ± .0252	.3996 ± .0233	2.8327 ± .1650	1.8439 ± .1074	.5918 ± .0342
(c), sin..	72	.7803 ± .0438	.3418 ± .0192	2.0149 ± .1133	.4474 ± .0252	.3120 ± .0175	2.5300 ± .1422	1.9405 ± .1090	.7717 ± .0433
cestata, all, sin..	168	.7716 ± .0283	.3477 ± .0128	2.1625 ± .0795	.4314 ± .0158	.3452 ± .0126	2.6226 ± .0965	1.8587 ± .0698	.6789 ± .0249
Plain, sin.....	8	.4975 ± .0838	.4092 ± .0690	2.0271 ± .3418	.3162 ± .0533	.2332 ± .0393	1.1180 ± .1814	1.7984 ± .3032	.7071 ± .1192
All, sin.....	176	.7654 ± .0275	.3514 ± .0126	2.1587 ± .0776	.4276 ± .0153	.3409 ± .0122	2.5827 ± .0928	1.8566 ± .0667	.6804 ± .0244
cestata (a), dex.	19	.8777 ± .0960	.3554 ± .0389	2.0329 ± .2224	.4044 ± .0442	.2929 ± .0320	2.1534 ± .2356	1.9323 ± .2114	.8775 ± .0960
(b), dex.	56	.8218 ± .0524	.4609 ± .0293	1.9243 ± .1226	.4442 ± .0283	.3643 ± .0232	2.0639 ± .1315	1.6378 ± .1044	.6781 ± .0428
(c), dex.	63	.7735 ± .0464	.3712 ± .0223	2.2658 ± .1361	.4358 ± .0262	.3042 ± .0182	2.6083 ± .1243	1.8628 ± .1119	.9285 ± .0558
cestata, all, dex.	138	.8188 ± .0332	.4011 ± .0163	2.1134 ± .0858	.4395 ± .0178	.3338 ± .0136	2.3859 ± .0969	1.7859 ± .0725	.8409 ± .0340
Plain, dex.....	10	.6945 ± .1047	.2088 ± .0314	1.6248 ± .2450	.3280 ± .0494	.1959 ± .0295	1.8330 ± .2765	2.3580 ± .3556	.6403 ± .0966
All, dex.....	148	.8110 ± .0318	.3999 ± .0157	2.0841 ± .0817	.4339 ± .0170	.3264 ± .0128	2.3597 ± .0925	1.8446 ± .0723	.8291 ± .0324

<sup>1</sup>The numbers are as follows: 29, 68 72, 169, 8, 177; 19, 57, 63, 139, 10, 149.

The figures for fecundity are high (table 215), with very little advantage on the part of any subordinate division.

TABLE 215.—*Partula otaheitana sinistralis*. *Tiamao Valley*.

Series.	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.
Unbanded, sin.....	8	7	87.5	14	6	20	2.86	2.50
Banded, sin.....	168	136	80.9	249	122	371	2.73	2.21
All, sin.....	176	143	81.2	263	128	391	2.74	2.22
Unbanded, dex.....	10	8	80.0	14	8	22	2.75	2.20
Banded, dex.....	139	121	87.0	213	130	343	2.83	2.49
All, dex.....	149	129	86.6	227	138	365	2.82	2.48
All.....	325	272	83.7	490	266	756	2.78	2.32

The data of heredity (table 216) give certain interesting results. *As observed*, the banded pattern is displayed by very few of the young, in comparison with its prevalence among the adults; as before, it is something that seems to develop late. The most notable point is the chiasma of the coil in inheritance, in such a way as to make the relative numbers almost the same in both the offspring and parental generations!

TABLE 216.—*Partula otaheitana sinistralis*. Tiamao Valley.

HEREDITY, FULL DATA.					
	Young, sin.		Young, dex.		Total.
	Plain.	Banded.	Plain.	Banded.	
Adults:					
Sin., plain.....	..	..	3	3	6
banded.....	36	65	2	19	122
Dex., plain.....	1	..	7	..	8
banded....	22	9	51	48	130
Total.....	59	74	63	70	266

SUMMARY. HEREDITY OF COLOR PATTERN.				SUMMARY. HEREDITY OF SPIRALITY.			
	Young, plain, sin. + dex.	Young, banded, sin. + dex.	Total.		Young, sinistral.	Young, dextral.	Total.
Adults:				Adults:			
Plain, sin. and dex...	11	3	14	Sinistral...	101	27	128
Banded, sin. and dex.	111	141	252	Dextral...	32	106	138
Total.....	122	144	266	Total.....	133	133	266

## VAIPUARII VALLEY.

Vaipuarii Valley is listed as the southernmost element of the western series rather than the westernmost member of the localities situated in the southern quadrant, because it lies beyond the main mountain ridge running upwards from Maraa, at the southwest corner of the island, to culminate in Mount Mahutaa, nearly 5,000 feet high. It has been stated that the area between Temarua and Orofere Valleys is a compact land-sector in which lie most of the areas inhabited by *sinistralis*. On the further slopes of the main ridge forming the spine of this sector are many valleys, mainly of secondary or tertiary size, among which only Vaipuarii is occupied by *sinistralis*; in the others *crassa* occurs.

Less than a mile intervenes between the mouth of Tiamao and that of Vaipuarii, and a still smaller distance separates the inward parts of the two valleys as they converge in the course of their upward trend. Yet the *sinistralis* colony of Vaipuarii is decidedly unlike that of Tiamao or of any eastward area. No dextral individuals were found in a series of 180 adults, 94 adolescents, and 119 young; furthermore, the shells attain a much larger size than in the neighboring valleys to the east.

About 22 per cent (exactly 38) are unstriped *phæa* shells, grading from *confluens* to *striata* in the distinctness of the cross-markings (plate 32, figs. 58 to 61). The

remainder are *cestata* (a) in 41 cases (plate 32, fig. 62) and *cestata* (b) with distinct bands in almost all of the other 101 instances (plate 32, figs. 63 and 64), although less than a score show some suffusion and approximate *cestata* (c) of other colonies; the last are too few to be separated as a distinct subclass.

The statistics (table 217) show that *cestata* (a) shells are stouter and shorter than the others, with shorter and relatively broader apertures, which are also more open than in the rest. The plain and banded classes are essentially alike. One point of note is that the pillar tooth is very slightly developed in the colony as a whole.

TABLE 217.—*Partula otaheitana sinistralis*. *Vaipuarii Valley*.

MEAN VALUE.									
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index. <sup>1</sup>
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
<i>cestata</i> (a) . . . . (b + c) . . . .	41	<i>mm.</i> 18.4012 ± .0831	<i>mm.</i> 10.5097 ± .0397	<i>p. ct.</i> 57.0122 ± .2208	<i>mm.</i> 9.6024 ± .0421	<i>mm.</i> 7.2512 ± .0335	<i>p. ct.</i> 75.5732 ± .2843	<i>p. ct.</i> 52.0610 ± .1678	1.0000 ± .0
	98	18.7143 ± .0588	10.5939 ± .0308	56.5102 ± .1435	9.6673 ± .0325	7.2673 ± .0250	75.1429 ± .1714	51.5306 ± .1206	1.0297 ± .0114
<i>cestata</i> all . . . . . <i>phæa</i> . . . . .	139	18.6226 ± .0488	10.5690 ± .0248	56.6582 ± .1211	9.6482 ± .0261	7.2634 ± .0205	75.2698 ± .1475	51.6870 ± .0993	1.1316 ± .0447
	37	18.6338 ± .0784	10.6189 ± .0468	56.9054 ± .2519	9.5811 ± .0519	7.2371 ± .0418	75.2568 ± .2805	51.2838 ± .1825	1.0211 ± .0081
All . . . . .	176	18.6244 ± .0419	10.5795 ± .0219	56.7102 ± .1094	9.6341 ± .0234	7.2568 ± .0185	75.2670 ± .1306	51.6022 ± .0877	1.0444 ± .0128
STANDARD DEVIATION.									
<i>cestata</i> , (a) . . . . (b + c) . . . .	41	0.7893 ± .0587	0.3773 ± .0281	2.0967 ± .1561	0.4003 ± .0298	0.3179 ± .0237	2.6995 ± .2010	1.5934 ± .1186	0.
	98	.8628 ± .0416	.4519 ± .0218	2.1068 ± .1015	.4779 ± .0230	.3678 ± .0177	2.5163 ± .1212	1.7696 ± .0853	.1697 ± .0081
<i>cestata</i> , all . . . . . <i>phæa</i> . . . . .	139	.8535 ± .0345	.4330 ± .0175	2.1163 ± .0856	.4573 ± .0184	.3591 ± .0145	2.5791 ± .1043	1.7365 ± .0702	.1438 ± .0057
	37	.7076 ± .0500	.4222 ± .0331	2.2719 ± .1781	.4683 ± .0367	.3772 ± .0295	2.5299 ± .1983	1.6462 ± .1361	.4085 ± .0316
All . . . . .	176	.8252 ± .0296	.4312 ± .0155	2.1522 ± .0773	.4604 ± .0165	.3636 ± .0131	2.5688 ± .0923	1.7258 ± .0620	.2543 ± .0090

<sup>1</sup>The numbers are, respectively, 41, 101, 142, 38, 180.

Relatively few snails were gravid at the time of collection (table 218) but those that were bore a goodly number of young and eggs. As heretofore, the banded pattern seems to develop late, for the facts as observed (table 218) certainly do not mean that a drastic change toward a colony composed of only unbanded shells is taking place.

TABLE 218.—*Partula otaheitana sinistralis*. *Vaipuarii*.

FECUNDITY.									HEREDITY OF PATTERN.			
Series.	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.		Young, plain.	Young, banded.	Total.
<i>cestata</i> . . . . .	142	97	68.3	156	107	263	2.71	1.85	Adults: Plain . . . . Banded . . .	9	3	12
<i>phæa</i> . . . . .	37	21	56.8	29	12	51	2.43	1.36		72	35	107
All . . . . .	179	118	65.9	185	119	304	2.58	1.69	Total . . . .	81	38	119

## SUMMARY AND CONCLUSION.

In presenting a general statement of the important points of the foregoing detailed description, almost the same expressions could be given as in the case of *sinistrorsa*. Not only are the principles of distribution and variation identical, with the same significance as before, but because the whole variety is so similar in its general features of color-analysis and color-composition, the specific facts also are essentially like those demonstrated through the study of the former primary variety.

I. *The colonies of sinistralis vary from valley to valley without relation to specific environmental influences.* Variations are displayed (a) in the relative numbers of the variety in the whole *Partula* population; (b) in the proportionate numbers of sinistral and dextral representatives; (c) in the color-composition of the colony, determined by the relative numbers assigned to the primary color-classes; and (d) in the intrinsic differentiation within the major color-divisions. The last-mentioned point is one that should receive special emphasis.

TABLE 219.—*Partula otaheitana sinistralis*. Summary statistical description, sinistral shells. Mean value.

Valley.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index. <sup>1</sup>
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
		mm.	mm.	p. ct.	mm.	mm.	p. ct.	p. ct.	
Teohu. . . . .	457	17.2636 ± .0244	9.9222 ± .0129	57.3665 ± .0681	8.8794 ± .0138	6.7639 ± .0110	76.1061 ± .0834	51.3403 ± .0565	2.6797 ± .0232
Papeiti. . . . .	474	16.6684 ± .0236	9.3359 ± .0130	55.9346 ± .0729	8.5506 ± .0129	6.5409 ± .0112	76.3439 ± .0794	51.1983 ± .0545	2.8926 ± .0187
Temarua. . . . .	539	16.8495 ± .0207	9.5644 ± .0112	56.6986 ± .0629	8.7480 ± .0114	6.7018 ± .0095	76.5376 ± .0710	51.8148 ± .0471	3.0624 ± .0158
Vaipoo. . . . .	61	17.0123 ± .0641	9.6672 ± .0341	56.8279 ± .1982	8.8574 ± .0354	6.7164 ± .0278	75.7459 ± .2280	52.0246 ± .1553	2.9033 ± .0852
Tearatapu. . . . .	30	16.7000 ± .1096	9.7067 ± .0530	58.2000 ± .2625	8.8800 ± .0720	6.8467 ± .0547	77.1333 ± .2707	53.1667 ± .2233	2.9333 ± .0895
Opiriroa. . . . .	152	18.2118 ± .0417	9.9605 ± .0208	54.5789 ± .1141	9.2395 ± .0232	7.0474 ± .0184	76.1382 ± .1436	50.6316 ± .0843	2.9671 ± .0399
Otuna. . . . .	346	18.5546 ± .0294	10.2896 ± .0159	55.3960 ± .0821	9.5566 ± .0161	7.2572 ± .0135	75.9220 ± .0962	51.3815 ± .0664	2.9222 ± .0279
Maruia. . . . .	103	18.0209 ± .0483	10.2767 ± .0234	57.0243 ± .1434	9.3427 ± .0290	7.2029 ± .0227	77.0825 ± .1853	51.7233 ± .1259	1.5895 ± .0606
Terechia. . . . .	69	17.6109 ± .0688	9.8623 ± .0326	55.8913 ± .1773	8.9667 ± .0317	6.7812 ± .0311	75.6014 ± .2225	50.8478 ± .1532	1.6286 ± .0748
Tiamao. . . . .	176	17.8148 ± .0389	10.1511 ± .0178	56.9034 ± .1097	9.2170 ± .0217	6.9193 ± .0173	74.9943 ± .1313	51.6364 ± .0944	1.4567 ± .0345
Vaipuarii. . . . .	176	18.6244 ± .0419	10.5795 ± .0219	56.7102 ± .1094	9.6341 ± .0234	7.2568 ± .0185	75.2670 ± .1306	51.6022 ± .0877	1.0444 ± .0128

<sup>1</sup>The numbers are greater in some cases, as given in the foregoing tables.

II. *The dimensions, proportionate measures, and the columellar tooth vary from valley to valley, again without any consistent relation to external influences.* The collated average values for the several characters in all of the colonies (table 219), the differences considered in geographical order (table 220), and the graphic representation (table 221), present the facts in their fullness. Intervalley migration may play a larger part than in the case of *rubescens* in keeping the colonies of neighboring areas more similar to one another, because the high degree of moisture and the growth of habitable forests at lower levels facilitate the passage from one region to a contiguous valley, which can not be the case in the drier portions of the island. The greater degree of resemblance, then, displayed by *sinistralis* associations would not be due to more similar ecological conditions, but to a genetic interchange, as it were, of the congenital characteristics inherent in the emigrants.

TABLE 221. *Partula otaheitana sinistralis*. Progressive variation of the colonies in geographical order, as regards range and mean value. (Sinistral group, full lines; dextral group, interrupted lines.)

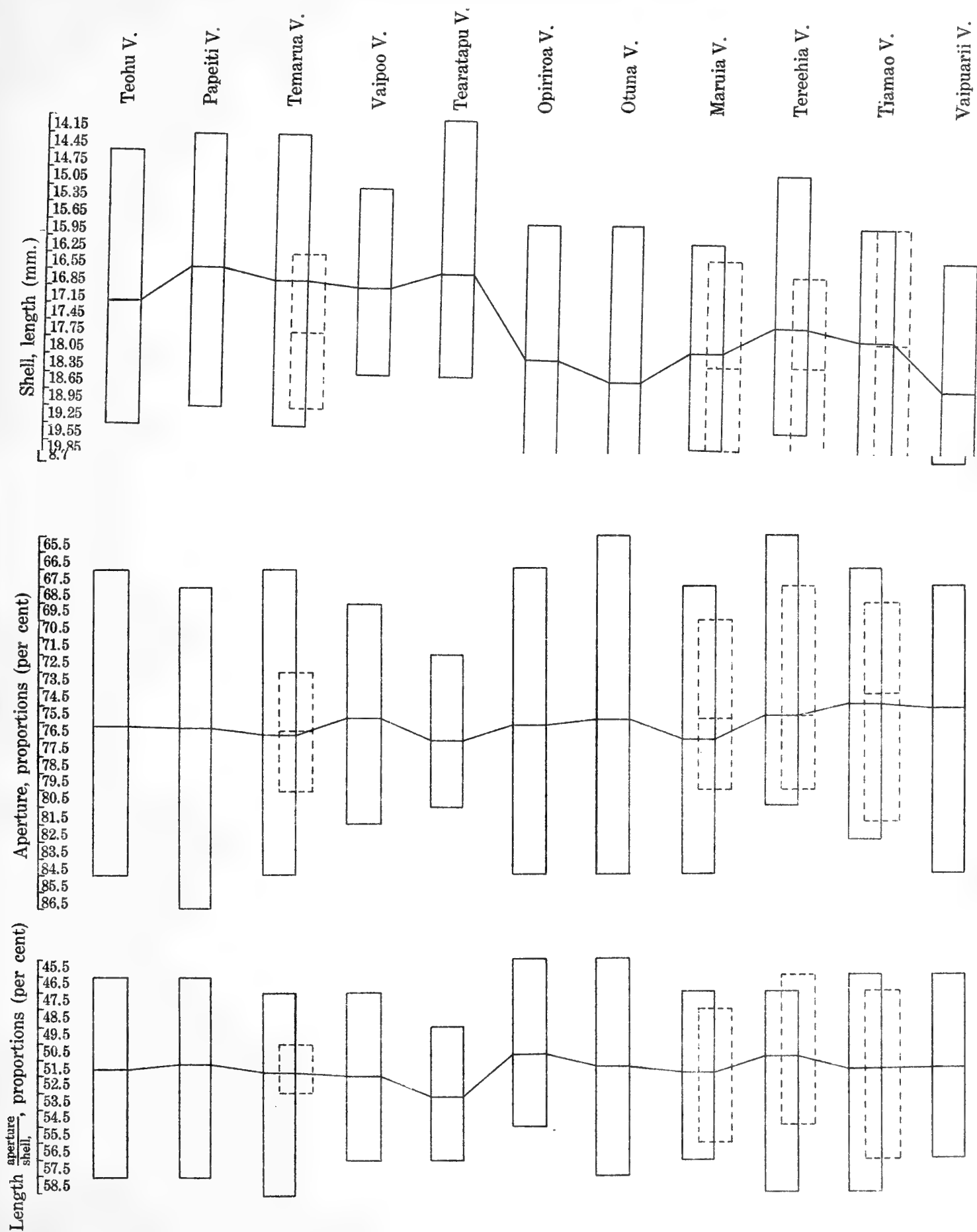
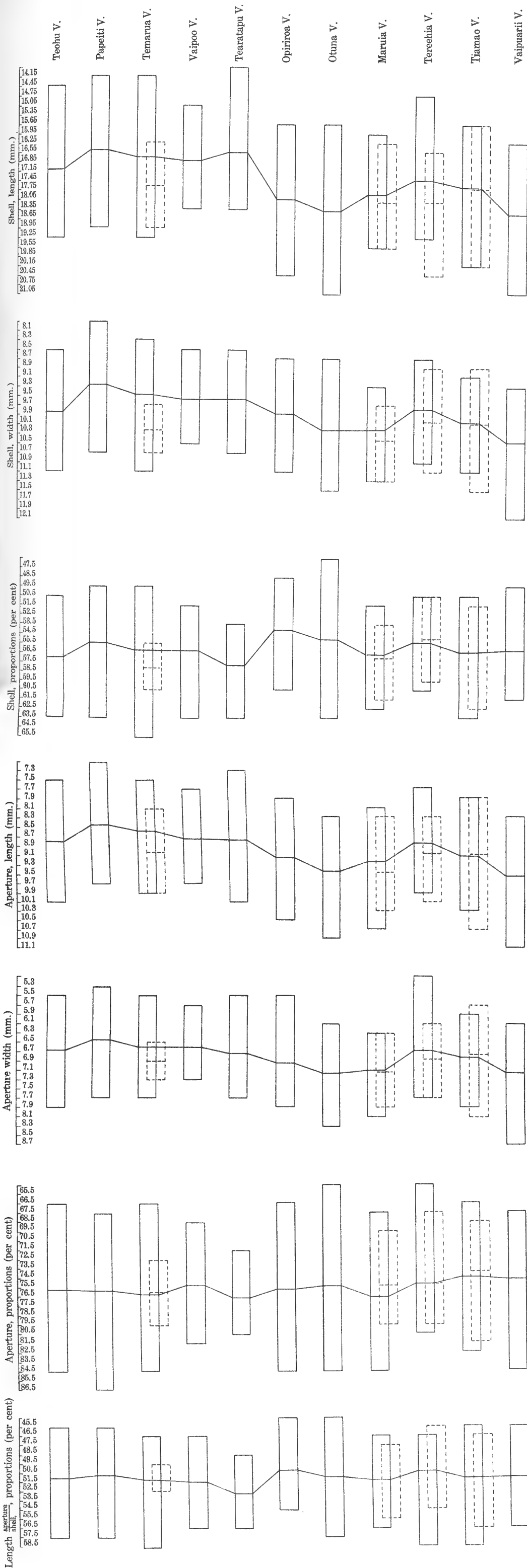




TABLE 221. *Partula otaheitana sinistralis*. Progressive variation of the colonies in geographical order, as regards range and mean value. (Sinistral group, full lines; dextral group, interrupted lines.)







III. *A collective description of the whole primary variety gives the basis for its comparison with other subspecies.* The dextral shells are not everywhere present and are not numerous enough to figure in this combined description. As before, two modes of effecting the consolidation are to be employed, with slightly divergent results (table 222). When the original data are united into one series, the result is a precise definition of the subspecies as it exists in the entire area of occupation. Viewing each colony as a genetic unit, the average of valley types gives a summary with a different biological significance. The color-characters of the primary variety as a whole are presented with sufficient fullness in the earlier description (table 196).

TABLE 220.—*Partula otaheitana sinistralis*. Progressive comparison of colonies, sinistral shells. Differences in mean value.

Valley.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index.
	Length.	Width.	Proportions.	Length.	Width.	Proportions.		
[Taharua]	mm.	mm.	p. ct.	mm.	mm.	p. ct.	p. ct.	
Teohu...	-1.3048±.0377	-0.4384±.0200	+1.6196±.1014	-0.6119±.0227	-0.4549±.0176	[+ 0.1967±.1324]	+ 0.3090±.0869	+1.3226±.0330
Papeiti...	- .5952±.0339	- .5863±.0183	-1.4319±.0998	- .3288±.0189	- .2230±.0157	+ .2378±.1151	[- .1420±.0785]	+ .2129±.0298
Temarua...	+ .1811±.0314	+ .2285±.0172	+ .7640±.0963	+ .1974±.0172	+ .1609±.0146	[+ .1937±.1065]	+ .6165±.0720	+ .1698±.0245
Vaipoo...	+ .1628±.0674	+ .1028±.0395	[+ .1293±.2070]	+ .1094±.0372	[+ .0146±.0294]	- .7917±.2388	[+ .2098±.1623]	[- .1591±.0866]
Tearatapu	- .3123±.1279	[+ .0395±.0640]	+1.3721±.3289	[+ .0226±.0802]	+ .1303±.0614	+ 1.3874±.3539	+ 1.1421±.2721	[+ .0300±.1236]
Opiroa...	+1.5118±.1173	+ .2538±.0569	-3.6211±.2862	+ .3595±.0243	+ .2007±.0578	- .9981±.3064	- 2.5351±.2405	[+ .0338±.0980]
Otuna...	+ .3428±.0510	+ .3291±.0262	+ .8171±.1406	+ .3171±.0282	+ .2098±.0228	[- .2162±.1728]	+ .7499±.1073	[- .0449±.0487]
Maruia...	- .5337±.0565	[- .0129±.0283]	+1.6283±.1652	- .2139±.0332	- .0543±.0264	+ 1.1605±.2088	+ .3418±.1423	-1.3327±.0777
Terehia...	- .4600±.0841	- .4144±.0401	-1.1330±.2280	- .3760±.0430	- .4217±.0385	- 1.4811±.2896	- .8755±.1983	[+ .0391±.0963]
Tiamao...	+ .2539±.0790	+ .2888±.0371	+1.0121±.2085	+ .2503±.0384	+ .1381±.0356	- .6071±.2583	+ .7886±.1797	- .1719±.0824
Vaipuarii...	+ .8096±.0572	+ .4284±.0282	[- .1932±.1509]	+ .4171±.0319	+ .3375±.0253	[+ .2727±.1852]	[- .0342±.1290]	- .4123±.0368

TABLE 222.—*Partula otaheitana sinistralis*. Collective description, sinistral shells. (No. = 2603, tooth : 2608).

Character.	Mean value.		Standard deviation.	
	Combined series.	Average of valley types.	Combined series.	Average of valley types.
Shell length, mm. ....	17.4493±.0139	17.5756	1.0549±.0098	0.7847
width, mm. ....	9.8536±.0073	9.9378±	.5553±.0051	.4019
proportions, per cent. ....	56.4063±.0312	56.5029	2.3578±.0221	2.1952
Aperture length, mm. ....	8.9975±.0074	9.0793	.5628±.0052	.4397
width, mm. ....	6.8536±.0057	6.9122	.4345±.0040	.3589
proportions, per cent. ....	76.1162±.0355	76.0793	2.6868±.0251	2.5903
Length aperture ÷ length shell, proportions, per cent. ...	51.4573±.0237	51.5788	1.7954±.0167	1.7775
Tooth, index. ....	2.5943±.0122	2.3709	.9277±.0086	.7146

## PARTULA OTAHEITANA CRASSA Pease.

## GENERAL CONSIDERATIONS.

With the exception of the southernmost valley (Vaipaurii, which harbors the last representatives of *sinistralis*) the valleys of the western quadrant are inhabited by the third group belonging to the triple series of the south and west. The snails of this division are distinguished as *Partula otaheitana crassa* because Pease gave the last name in manuscript to certain characteristic specimens sent him by Garrett; *crassa*, however, is not an independent species, but is to be regarded as a primary variety of *P. otaheitana* allied closely to *sinistralis* and *sinistrorsa*, a relationship always to be kept in mind.

The only description of *crassa* consists of passing comments in Garrett's monograph, quoted previously. Its affinities with *sinistralis* and through this with *sinistrorsa* are indicated by its almost invariable reversal in coil, by the preponderance of shells with a dentate columella, and by the brown or yellow-brown ground color displayed by the shells of nearly all colonies. The principal color-classes conform to those of *sinistralis*; in certain instances the plain phæa examples are differentiated into the *striata* and *confluens* subgroups to a greater degree than heretofore. The banded shells, still to be called *cestata*, are much less plainly striped. The distinctive qualities that will appear in the serial analysis of the colonies are few but important; among them, the prevalence of the strigated color-pattern and the close coiling of the shells are the most noteworthy.

Within its territory, *crassa* is clearly differentiated into subordinate groups, some of which are so sharply distinguished as almost to be worthy of separation as subspecies of *otaheitana*; their respective areas of occupation are likewise distinct. Northward from Vaitupa, which adjoins Vaipaurii, the valleys as far as Orofere are inhabited by typical *crassa* colonies, to be considered collectively as the "southern series." But in the next two areas—Aoua and Papehū—the shells present entirely different colonial characters in the way of color and form; undoubtedly these novel associations are descendants of an original *crassa* stock, but their peculiarities are such as to demand a definite taxonomic term, for which *occidentalis* is chosen on account of their western situation. Specifically, yellow and red colors approaching those of *P. otaheitana rubescens* are displayed, to the virtual exclusion of the usual *crassa* brown. Beyond their valleys, one finds typical *crassa* ("northern series") until Punaruu is passed and Taapuna Valley is attained, where again the basic type gives place to another subdivision, named *P. otaheitana crassa aberrans* on account of its divergence in color and form. In brief, then, the subspecies or primary variety *crassa* is differentiated intrinsically and geographically into *crassa* proper, *crassa occidentalis*, and *crassa aberrans*; the range of the first is interrupted by the territory of the second, and the area of the third lies to the extreme north beyond that of the last colony of *crassa* proper. The relative numbers assigned to the component color-classes, and the total numbers of adults collected in the several valleys, are given in table 223.

TABLE 223.—*Partula otaheitana crassa*. Numerical relations.

Division and valley.	No. of adults.	Per cent sin., cestata.	phæa striata.	Per cent sin., phæa confluens.	"Red" ["medium"]	"Yellow" ["light"]	Dextral, phæa confluens.
Southern <i>crassa</i> :							
Vaitupa.....	321	7.5	62.9	29.6	....	....	....
Atitara.....	154	11.7	79.2	8.4	....	....	0.6
Oroferre.....	197	4.6	95.4		....	....	....
<i>occidentalis</i> :							
Aoua.....	304	....	....	0.7	52.5	46.8	....
Papehue.....	156	....	....	0.7	44.7	54.5	....
Northern <i>crassa</i> :							
Atehi.....	413	68.5	31.4		....	....	....
Maruapoo.....	135	12.6	87.4		....	....	....
Punaruu.....	557	2.9	97.1		....	....	....
<i>aberrans</i> :							
Taapuna.....	1225	[2.2]	[46.1]		[40.5]	[11.1]	....

<sup>1</sup>The bracketed figures refer to 180 perfect specimens.

## SOUTHERN CRASSA SERIES—VAITUPA TO OROFERE VALLEYS.

## VAITUPA VALLEY.

Vaitupa is one of the series of valleys grooved in the westward slopes of the great triangular land-mass that lies between Temarua in Papara and Oroferre in Pæa. The main ridge of this sector, tending downward from Mount Ivirairai, reaches the coast at Maraa Point, at the southeastern corner of the island. Hence the line of contact between the area of *crassa* and that of *sinistralis* does not coincide with this ridge as a natural boundary, but lies between Vaitupa and Vaipuarii; the latter belongs geographically in the western quadrant, although its *otaheitana* inhabitants are close relatives of the southern associations.

The snails were all sinistral in a collection of 321 adults, 37 adolescents, and 149 embryonic young dissected out of their parents. Among the first, the color-classes are represented as follows: phæa striata, 202, or 62.9 per cent; phæa confluens, 95, or 29.6 per cent, cestata, 24, or 7.5 per cent. In the first division (plate 33, figs. 1 to 5), the ground-color is yellowish brown and is crossed by narrow and distinct strigations, sometimes thickly crowded; decortication gives a peculiar pallid cast to the shell (plate 33, fig. 1). The phæa confluens shells (plate 33, figs. 6 to 9) agree with those of the same name among *sinistralis* colonies, having indistinct markings that in the more deeply colored examples simulate the uniform color of *solida*; the shells of figures 6 and 9 display abnormalities in color and lip respectively. The banded or cestata shells are never sharply striped (plate 33, figs. 10 to 15), and it is interesting to note that their ground-colors are similar to those of either striata or confluens. Usually only a single band is present, which corresponds in position with the median marking in three-banded *sinistralis*, and with the lower (right) portion of the median zonal stripe of typical *sinistrorsa* examples with bands. More rarely, a faint sutural marking is displayed (fig. 12), while in one instance only (fig. 10) the second stripe is midway between the "median" one and the suture.

The aspect of the aperture is novel, as the figures show. Where the inner margin of the lip sweeps upwards to the columella, there is a more or less pronounced nodosity, which is displayed by all shells, although it is less developed in the phæa confluens group.

Statistically (table 224) the two groups of unbanded shells prove to be virtually identical; the *cestata* group departs from the others in certain intrinsic characters of the aperture and in its relative length as compared with that of the whole shell. Taken collectively, the shells of this colony fall far below those of the *sinistralis* association of Vaipuarii (*vide ante*) in absolute dimensions, while they are more tightly coiled as indicated by the greater proportionate measures.

TABLE 224.—*Partula otaheitana crass.* Vaitupa Valley.

MEAN VALUE.									
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index. <sup>1</sup>
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
		mm.	mm.	p. ct.	mm.	mm.	p. ct.	p. ct.	
phæa striata . . . . .	199	17.1997 ± .0346	9.6819 ± .0171	56.2035 ± .0935	9.0920 ± .0192	6.7905 ± .0153	74.6558 ± .1235	52.7663 ± .0833	2.3466 ± .0469
confluens . . . . .	94	17.1053 ± .0505	9.6575 ± .0255	56.4574 ± .1679	9.0447 ± .0279	6.7213 ± .0225	74.2766 ± .1796	52.7871 ± .1195	2.3790 ± .0682
cestata . . . . .	24	17.1250 ± .0961	9.7334 ± .0403	56.6667 ± .2772	8.9834 ± .0483	6.7834 ± .0389	75.1666 ± .3502	52.4167 ± .2780	2.5834 ± .1313
All . . . . .	317	17.1661 ± .0274	9.6785 ± .0135	56.3139 ± .0800	9.0697 ± .0151	6.7694 ± .0121	74.5820 ± .0981	52.7461 ± .0666	2.3739 ± .0372
STANDARD DEVIATION.									
phæa striata . . . . .	199	0.7235 ± .0244	0.3576 ± .0121	1.9561 ± .0661	0.4029 ± .0136	0.3213 ± .0108	2.5834 ± .0873	1.7434 ± .0589	0.9892 ± .0332
confluens . . . . .	94	.7256 ± .0357	.3671 ± .0180	2.4141 ± .1187	.4015 ± .0197	.3231 ± .0159	2.5812 ± .1270	1.7174 ± .0845	.9860 ± .0482
cestata . . . . .	24	.6978 ± .0679	.2925 ± .0285	2.0138 ± .1960	.3508 ± .0341	.2824 ± .0275	2.5440 ± .2476	2.0190 ± .1966	.9538 ± .0928
All . . . . .	317	.7235 ± .0194	.3577 ± .0096	2.1120 ± .0566	.4001 ± .0107	.3200 ± .0086	2.5908 ± .0694	1.7571 ± .0471	.9877 ± .0263

<sup>1</sup>The numbers are, respectively, 202, 95, 24; 321.

The matter of the pillar tooth (table 225) demands a special word. In so far as some shells of this and of other *crassa* colonies display this feature, it may be said that *crassa* is dentated; but it is by no means true, as Garrett unqualifiedly states (p. 220, this memoir) that all shells possess the pillar tooth. The full array for the Vaitupa series is sufficient to establish the point that the tooth is a morphological feature of the colony but not one displayed by all of its constituents.

TABLE 225.—*Partula otaheitana crassa.* Vaitupa Valley.

TOOTH.						
Series.	None.	Trace.	Tooth.	Large.	Very large.	Total.
phæa striata.....	51	50	86	10	5	202
confluens.....	19	34	32	7	3	95
cestata.....	3	8	10	2	1	24
All.....	73	92	128	19	9	321

FECUNDITY.								
Series.	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.
phæa striata.....	200	150	75.0	252	105	357	2.38	1.78
confluens...	94	72	76.6	136	33	169	2.35	1.80
cestata.....	24	21	87.5	34	11	45	2.14	1.87
All.....	318	243	76.4	422	149	571	2.35	1.80

In fecundity (table 225) at the time of collection, the figures for the several groups are sufficiently alike to render the occurrence of differential fertility improbable.

All of the 149 young were sinistral, unbanded, and light or medium brown in color. The faintness of the band even in the adults, when present, together with the above, would indicate that the distinctive markings of the *cestata* shells are developed only in postembryonic life. In this connection we may note that only 2 among 37 adolescents, or 5.4 per cent, showed a band, as compared with 7.5 per cent *cestata* among the adults.

#### ATITARA VALLEY.

In this region the *crassa* association agrees in all essential respects with the colony of Vaitupa, saving only that one dextral mutant of plain coloration was found in a series of 154 adults and 17 adolescents. The principal color-types are represented as follows:

	No.	Per cent.
<i>phæa striata</i> , sin. ....	122	79.2
<i>phæa confluens</i> , sin. ....	13	8.4
<i>cestata</i> , sin. ....	18	11.7
<i>phæa striata</i> , dex. ....	1	0.6

The notable points are the greater number of banded shells and the smaller relative numbers of *phæa confluens*. In addition to the dextral mutant (plate 33, fig. 21) the illustrations show shells of unusual form or size or color (plate 33, figs. 16 to 20).

TABLE 226.—*Partula otaheitana crassa*. Atitara Valley.

MEAN VALUE.									
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
Plain, sin. . . .	135	<i>mm.</i> 16.6523 ± .0452	<i>mm.</i> 9.7074 ± .0234	<i>p. ct.</i> 58.1444 ± .1286	<i>mm.</i> 9.0082 ± .0273	<i>mm.</i> 6.7741 ± .0210	<i>p. ct.</i> 75.1222 ± .1336	<i>p. ct.</i> 53.9444 ± .1130	2.7333 ± .0475
Banded, sin. . .	18	17.0667 ± .0924	9.7556 ± .0447	57.0556 ± .2760	9.0889 ± .0575	6.8000 ± .0465	74.4445 ± .3287	53.1111 ± .2957	2.7778 ± .1131
All, sin. . . . .	153	16.7206 ± .0426	9.7131 ± .0214	58.0163 ± .1196	9.0176 ± .0251	6.7771 ± .0193	75.0425 ± .1247	53.8464 ± .1066	2.7386 ± .0440
Plain, dex. . . .	1	16.25	9.50	58.50	9.30	6.90	73.50	56.50	3
STANDARD DEVIATION.									
Plain, sin. . . .	135	0.7782 ± .0320	0.4039 ± .0165	2.2160 ± .0909	0.4706 ± .0193	0.3617 ± .0148	2.3025 ± .0945	1.9462 ± .0799	0.8183 ± .0336
Banded, sin. . .	18	.5814 ± .0653	.2813 ± .0316	1.7362 ± .1952	.3619 ± .0406	.2925 ± .0329	2.0675 ± .2324	1.8601 ± .2091	.7114 ± .0800
All, sin. . . . .	153	.7805 ± .0301	.3918 ± .0151	2.1936 ± .0846	.4599 ± .0177	.3543 ± .0137	2.2865 ± .0882	1.9547 ± .0754	.8066 ± .0311

On the basis of the statistics (table 226) the banded group proves to be decidedly different from the rest in length and in the several proportionate measures. Indeed, the departures are difficult to understand unless there is some degree of selective mating. On the whole, the shells are far smaller and more tightly coiled than in Vaitupa. The tooth attains a greater degree of development as a colonial feature.

In fecundity, as in structure, the small series of banded snails is different from the others to a remarkable degree (table 227), for it shows a relatively high percentage of gravid adults and a high fertility among them. Although it is conceivable that one group might resume breeding activity before the other, the eggs are about 4 to 1 of the young in both series; so that no difference in the *time* of breeding can be invoked to account for the discrepancies.

The embryonic young are all sinistral and devoid of the band. Apparently in this valley, as before, *cestata* shells do not display the stripe until late in life.

TABLE 227.—*Partula otaheitana crassa*. Atitara Valley. Fecundity.

Series.	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.
Plain, sin. . . . .	91	45	49.4	63	16	79	1.76	0.88
Banded, sin. . . . .	11	8	72.7	14	4	18	2.25	1.63
All, sin. . . . .	102	53	52.0	77	20	97	1.83	0.95

#### OROFERE VALLEY.

In Garrett's descriptive account, the type locality of *crassa* is given as Faahuaite Valley, which from intrinsic evidence is to be identified with the area now called Orofere on the charts, and Faarahi colloquially. The last name means simply "large valley" and is used because the adjoining ravines on both sides are much smaller. The identification is based upon the existence of typical *crassa* in Orofere, and also upon the fact that this valley is the only large element lying between the range of *sinistralis* and Punaauia Valley, the home of the original *Partula nodosa*; Garrett mentions only the greater clefts, and speaks of Faahuaite as followed by Punaruu (Punaauia). As the name "Faahuaite" was not known to the local chiefs consulted by me, we must conclude either that Garrett's information was incorrect or that his memory was at fault. In any case, there is no doubt whatever that the valley herein called Orofere is the place specified by the earlier author as the habitat of *crassa* in his time.

Collections were secured in 1907 and 1908. On the first occasion, snails were taken in the lower valley up to a point about 3 miles from the coast and a mile beyond the point where *Partulæ* were first met at a barometric level of 200 feet. In 1908 a deeper journey was made, but as in the first year *Partulæ* were found in scattered situations and in small numbers. The two series were alike only in the relative preponderance of *phæa* shells (95.5 per cent and 95.2 per cent, respectively) and in the lack of their sharp differentiation into *striata* and *confluens*; typical representatives of these are found, but the intergrades are so numerous as to render impossible a classification like that of Vaitupa and Atitara shells. The illustrations (plate 33, figs. 22 to 28) show several representatives of this class, typical and aberrant. *Cestata* shells are few, 6 being taken in 1907 and 3 in 1908; usually the distinctive markings are faint, but in the specimen of plate 33, figure 30, two bands are sharply defined. The shell of plate 33, figure 29, is bicolored upon the last whorl through the spread of the median band over the entire lower, or right, area.

The full table of statistics (table 228) shows that the series from the lower situation (1907) comprises shells that, as compared with those of the more inland region, are longer, wider, and stouter, with longer and wider but less rounded apertures. Both series have the tooth well-developed.

TABLE 228.—*Partula otaheitana crassa*. Orofere Valley.

MEAN VALUE.									
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
phæa, 1907... cestata, 1907.	127	mm. 17.7263 ± .0586	mm. 10.6401 ± .0340	p. ct. 59.9960 ± .1433	mm. 9.5629 ± .0316	mm. 7.1960 ± .0256	p. ct. 75.2693 ± .1496	p. ct. 53.8937 ± .1044	3.2969 ± .0491
	6	18.4000 ± .2101	10.7666 ± .1374	58.0000 ± .6506	10.0000 ± .1221	7.4000 ± .1262	74.5000 ± .6930	54.1666 ± .5430	3.5000 ± .1377
All, 1907....	133	17.7567 ± .0559	10.6458 ± .0331	59.9060 ± .1420	9.5828 ± .0311	7.2053 ± .0253	75.1391 ± .1481	53.9068 ± .1034	3.3060 ± .0473
phæa, 1908... cestata, 1908.	60	17.0500 ± .0863	10.1000 ± .0515	59.1333 ± .2776	9.2333 ± .0481	7.0100 ± .0414	75.7666 ± .2275	54.0666 ± .2099	3.2667 ± .0779
	3	17.6500 ± .2753	10.1666 ± .2570	57.5000 ± .3180	9.1000 ± .1272	6.9666 ± .2044	76.1666 ± 1.4687	51.5000 ± .3180	3.6667 ± .1836
All, 1908....	63	17.0786 ± .0840	10.1031 ± .0505	59.0555 ± .2665	9.2269 ± .0463	7.0079 ± .0406	75.7857 ± .2278	53.9444 ± .2056	3.2381 ± .0753
All. ....	196	17.5388 ± .0490	10.4714 ± .0303	59.6327 ± .1303	9.4684 ± .0271	7.1418 ± .0220	75.3469 ± .1252	53.9184 ± .0965	3.2842 ± .0402
STANDARD DEVIATION.									
phæa, 1907... cestata, 1907.	127	0.9799 ± .0414	0.5861 ± .0240	2.3939 ± .1013	0.5281 ± .0223	0.4288 ± .0181	2.5001 ± .1058	1.7441 ± .0738	0.8231 ± .0347
	6	.7632 ± .1486	.4990 ± .0971	2.3627 ± .4600	.4435 ± .0863	.4582 ± .0892	2.5166 ± .4900	1.9720 ± .3839	.5000 ± .0945
All, 1907....	133	.9567 ± .0395	.5658 ± .0234	2.4280 ± .1004	.5322 ± .0220	.4322 ± .0179	2.5320 ± .1047	1.7681 ± .0731	.8124 ± .0334
phæa, 1908... cestata, 1908.	60	.9914 ± .0610	.5910 ± .0364	3.1879 ± .1963	.5534 ± .0340	.4753 ± .0293	2.6132 ± .1608	2.4109 ± .1484	.8945 ± .0551
	3	.7071 ± .1954	.6599 ± .1817	.8165 ± .2248	.3266 ± .0899	.5249 ± .1445	3.7715 ± 1.0385	.8165 ± .2248	.4714 ± .1298
All, 1908....	63	.9881 ± .0594	.5947 ± .0357	3.1359 ± .1884	.5455 ± .0327	.4778 ± .0287	2.6811 ± .1611	2.4190 ± .1454	.8858 ± .0532
All. ....	196	1.0175 ± .0346	.6286 ± .0214	2.7053 ± .0921	.5617 ± .0192	.4568 ± .0155	2.5984 ± .0885	2.0021 ± .0682	.8372 ± .0284

TABLE 229.—*Partula otaheitana crassa*. Orofere Valley. Fecundity.

Series.	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.
phæa, 1907.....	110	71	64.5	91	47	138	1.94	1.25
cestata, 1907.....	4	3	75.0	6	2	8	2.67	2.00
All, 1907.....	114	74	64.9	97	49	146	1.97	1.28
phæa, 1908.....	58	43	74.1	67	32	99	2.30	1.71
cestata, 1908.....	3	2	66.7	1	1	2	1.00	0.67
All, 1908.....	61	45	73.8	68	33	101	2.24	1.66

Recognizing the uncertainty of the figures relating to the cestata class, it is interesting none the less that its components are larger in both the inland and outward collections. The data referring to the aperture show a divergence of cestata from phæa in opposite directions in all three determinations, and the same is true of the figures for the relative length of aperture and shell. These facts signify a sporadic production of banded shells from widely different phæa parents.

The statistics of fecundity (table 229) are noteworthy because the rates are different in the two annual series, although they were taken at the same time of the year, and because the *cestata* differ in opposite ways from the *phæa* class; the numbers of the latter are too few, however, to be really significant.

The young shells in all cases were sinistral and unbanded.

PARTULA OTAHEITANA CRASSA OCCIDENTALIS SUBVAR. NOV.—AOUA AND PAPEHUE VALLEYS.

The two valleys just to the north of Orofere, namely, Aoua and Papehue, are occupied by *otaheitana* associations which differ in certain striking ways from the *crassa* colonies previously described. Their color-composition is their most prominent distinctive feature; no banded or *cestata* individuals and very few brown *phæa confluens* are to be found, while the bulk of the population in both cases is made up of red-shelled and yellow-shelled snails that resemble *rubescens* in colors as well as in their sinistral coil. On account of their geographical situation, the two colonies are treated under the quaternary term *occidentalis*.

Although the topography of the western sector has been described earlier, both in the general section and also in connection with the colonial distribution of *Partula clara* and *Partula nodosa*, certain essential points demand specific mention again. The land-mass between Orofere and Punaruu is a compact triangular sector forming the coastward slopes of the mountain peaks of Mahutaa (4,943 feet) and Taiti (4,589 feet). The ravines and gullies north of Orofere grade regularly from Aoua, which is the longest and narrowest, to Papehue, Atehi, and Maruapoo—the last of which is the shortest and smallest of the series. We have learned how *Partula nodosa* and *Partula clara* are differentiated in the valleys of this sector; it is interesting to find that in the two habitable areas of Aoua and Papehue there is a clearly marked quaternary form of *Partula otaheitana* as well.

The collections from Aoua were secured during two excursions in 1907, and comprise 650 adults, 116 adolescents, and 231 embryonic young obtained from the first-named. From Papehue 143 adults and 84 adolescents were taken in 1906 and in 1907; from the former only 12 embryonic records are at hand, because the full-grown snails were kept alive for study and transport to the home laboratory. The absolute and relative numbers of adults assigned to the three color-groups are as follows:

Valley and year.	Number.			Per cent.		
	Yellow.	Red.	Brown.	Yellow.	Red.	Brown.
Aoua, 1907.....	304	341	5	46.8	52.5	0.7
Papehue, 1906.....	40	29	0	58.0	42.0	...
1907.....	38	35	1	51.3	47.3	1.3
All.....	78	64	1	54.5	44.7	0.7

The yellow class (plate 33, figs. 31 to 36, 46, and 47) comprises individuals that grade from whitish yellow to a rich yellow-orange, invariably lacking any tinge of red; the apex is often of a more intense hue, but it is never purple or red, as in some



of the yellow members of *rubescens* colonies. Shells of the second class (plate 33, figs. 37 to 42, 48 and 49) are red, reddish-brown, or pink in a decorticated condition, and usually their colors are more intensely red on the spire. They do not grade into the seal-brown *phæa confluens* type (plate 33, figs. 43 to 45), which are clearly discontinuous with them; the last are the only ones that are counterparts in all respects of typical *crassa* individuals from Orofere and other southward valleys. All shells are sinistral, and all display the nodosity of the columella margin of the aperture. The tooth is especially developed in the Aoua colony, thus giving an important contrast with *rubescens*, to which *occidentalis* is closely similar, save in size and in the plicated margin of the aperture.

The statistics relating to the standard characters of the Aoua shells (table 230) indicate much similarity of the yellow and red classes, although some differences of possible significance appear. The brown shells, although few in number, depart consistently from their associates, in ways that suggest their genetic independence; their variabilities afford additional indication of their separateness.

TABLE 230.—*Partula otaheitana crassa occidentalis*. Aoua Valley.

MEAN VALUE.									
Series. <sup>*</sup>	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index. <sup>1</sup>
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
		<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>p. ct.</i>	
Yellow...	293	17.1694 ± .0339	9.9689 ± .0172	57.9982 ± .0960	9.1580 ± .0182	6.9375 ± .0135	75.6194 ± .0970	53.2372 ± .0718	2.7138 ± .0291
Red.....	337	17.1625 ± .0313	9.9314 ± .0104	57.7759 ± .0847	9.1113 ± .0164	6.8988 ± .0139	75.6395 ± .0982	52.9926 ± .0721	2.8006 ± .0246
Brown...	5	16.5500 ± .3082	9.7000 ± .2055	58.3000 ± .2257	8.9400 ± .1894	6.7800 ± .1119	76.1000 ± .6211	53.3000 ± .3518	2.8000 ± .2257
All.....	635	17.1609 ± .0230	9.9469 ± .0116	57.8827 ± .0632	9.1315 ± .0124	6.9157 ± .0097	75.6339 ± .0689	52.1078 ± .0519	2.7600 ± .0188
STANDARD DEVIATION.									
Yellow...	293	0.8603 ± .0240	0.4380 ± .0122	2.4377 ± .0678	0.4615 ± .0129	0.3443 ± .0095	2.4612 ± .0686	1.8329 ± .0508	0.7524 ± .0206
Red.....	337	.8519 ± .0221	.2842 ± .0073	2.3069 ± .0599	.4465 ± .0116	.3783 ± .0098	2.6744 ± .0694	1.9627 ± .0510	.6729 ± .0174
Brown...	5	1.0217 ± .2179	.6812 ± .1453	.7483 ± .1596	.6280 ± .1339	.3710 ± .0791	2.0591 ± .4392	1.1662 ± .2487	.7483 ± .1596
All.....	635	.8590 ± .0163	.4332 ± .0082	2.3631 ± .0447	.4633 ± .0088	.3637 ± .0069	2.5741 ± .0487	1.9398 ± .0367	.7131 ± .0133

<sup>1</sup>The numbers are, respectively, 304, 341, 5; 650.

An analysis of the Papehue colony on the basis of the statistical determinations (table 231) must be more complex, because the collections of two different years are involved, the first of which (1906) was taken in the lower valley, while that of 1907 was secured from a more interior situation. The two color-classes of the first year do not differ greatly; their correspondents of the second series differ widely in absolute measure, but to insignificant degrees in proportionate measures; the single brown shell is very aberrant, and not in the directions from the average taken by the brown individuals of Aoua. Comparing the two annual series, it appears that the outer colony comprises larger shells, with apertures of lesser relative length. At several other points in the foregoing sections, when it was possible to compare collections taken at different distances from the coast in a single valley, the same

result was obtained (*cf.* especially Pirai and Papenoo); here again the interpretation is suggested that more severe conditions obtaining in the lowlands eliminate the smaller and weaker individuals.

TABLE 231.—*Partula otaheitana crassa occidentalis*. Papehue Valley.

MEAN VALUE.									
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index. <sup>1</sup>
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
		<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>p. ct.</i>	
Yellow, 1906	40	17.9675 ± .0941	10.1900 ± .0424	56.0750 ± .2665	9.4650 ± .0495	6.9900 ± .0413	75.0500 ± .2930	52.5750 ± .1622	1.6000 ± .0666
Red, 1906 . .	28	17.8571 ± .1028	10.2143 ± .0637	57.0715 ± .2978	9.4714 ± .0620	7.0857 ± .0446	74.6785 ± .3492	53.2857 ± .2230	1.6207 ± .0895
All, 1906 . . .	68	17.9206 ± .0699	10.2000 ± .0362	56.4559 ± .2020	9.4676 ± .0387	7.0294 ± .0307	74.2500 ± .2263	52.7059 ± .1455	1.6087 ± .0539
Yellow, 1907	36	17.6000 ± .1001	9.9055 ± .0454	56.3334 ± .2808	9.0056 ± .0617	6.8167 ± .0438	75.3888 ± .2924	51.1112 ± .2237	1.7105 ± .0829
Red, 1907 . .	32	17.9000 ± .1019	10.1375 ± .0557	56.5313 ± .3032	9.1375 ± .0570	6.9500 ± .0417	75.9687 ± .2732	51.0940 ± .1997	1.6471 ± .1116
Brown, 1907	1	18.35	10.30	55.50	9.14	7.10	75.50	51.50	1.0
All, 1907 . . .	69	17.7500 ± .0717	10.0188 ± .0364	56.4131 ± .2035	9.0739 ± .0422	6.8826 ± .0299	75.6594 ± .1980	51.1087 ± .1490	1.6713 ± .0680
All . . . . .	137	17.8354 ± .0503	10.1088 ± .0262	56.4489 ± .1438	9.2693 ± .0308	6.9555 ± .0218	74.7599 ± .1561	51.9015 ± .1139	1.6409 ± .0437
STANDARD DEVIATION.									
Yellow, 1906	40	0.8823 ± .0665	0.3973 ± .0300	2.4989 ± .1884	0.4645 ± .0350	0.3872 ± .0292	2.7472 ± .2072	1.5207 ± .1147	0.6244 ± .0471
Red, 1906 . .	28	.8066 ± .0727	.4999 ± .0450	2.3365 ± .2106	.4861 ± .0438	.3502 ± .0315	2.7393 ± .2469	1.7496 ± .1577	.7150 ± .0633
All, 1906 . . .	68	.8549 ± .0494	.4426 ± .0256	2.4700 ± .1428	.4735 ± .0273	.3754 ± .0217	2.7673 ± .1600	1.7786 ± .1029	.6641 ± .0381
Yellow, 1907	36	.8902 ± .0708	.4041 ± .0321	2.4980 ± .1985	.5487 ± .0436	.3898 ± .0310	2.6014 ± .1600	1.9900 ± .1581	.7577 ± .0586
Red, 1907 . .	32	.8551 ± .0720	.4675 ± .0394	2.5430 ± .2144	.4781 ± .0403	.3500 ± .0295	2.2911 ± .1932	1.6746 ± .1412	.9648 ± .0789
All, 1907 . . .	69	.8827 ± .0507	.4483 ± .0257	2.5064 ± .1439	.5196 ± .0298	.3679 ± .0211	2.4387 ± .1400	1.8354 ± .1053	.8609 ± .0481
All . . . . .	137	.8729 ± .0163	.4545 ± .0185	2.4947 ± .1017	.5349 ± .0218	.3788 ± .0154	2.7098 ± .1104	1.9759 ± .0805	.7722 ± .0309

<sup>1</sup>The numbers are, respectively, 40, 29, 69; 38, 34, 1, 73; 142.

TABLE 232.—*Partula otaheitana crassa occidentalis*. Aoua and Papehue Valleys. Fecundity.

Series.	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.
Aoua, yellow . . . . .	295	213	72.2	367	116	483	2.27	1.64
red . . . . .	318	242	76.1	419	114	533	2.20	1.67
brown . . . . .	5	3	60.0	3	1	4	1.33	0.80
Aoua, all . . . . .	618	458	74.1	789	231	1,020	2.23	1.65
Papehue, 1906 . . . . .	8	2	25.0	3	3	6	3.00	0.75
Papehue, yellow, 1907 . .	31	9	29.0	13	5	18	2.00	0.58
red, 1907 . . . . .	35	16	45.7	24	4	28	1.75	0.80
brown, 1907 . . . . .	1	0	0	...	...	...	...	...
Papehue, all, 1907 . . . . .	67	25	37.3	37	9	46	1.84	0.69

The pillar tooth is developed to different degrees in the two associations. In addition to the differences indicated by the diverse averages of the tables, we may cite the fact that only 73 out of 650 in the Aoua colony lack some growth, while 71 out of 143 from Papehue are devoid of any trace of the feature.

As regards fecundity (table 232) the Aoua snails displayed an average degree of reproductive activity, while the Papehue collection of the same time and year (1907) gave astonishingly low figures, both of gravid individuals and of average contents. Unfortunately the data for the 1906 series from the latter valley are scanty, but they also indicate a low rate of productivity.

The data of heredity (table 233) are particularly valuable for two matters of importance, namely, the relation of the yellow and red color-classes to one another and the relation of the brown class to the prevalent types. The figures show that the yellow and red forms interbreed and that the relative numbers are essentially the same among the young and among the parents. A yellow-shelled snail of Aoua bore one young with a yellowish-brown shell; this is probably *phæa*.

TABLE 233.—*Partula otaheitana crassa occidentalis*.

HEREDITY, AOUA VALLEY.				HEREDITY, PAPEHUE VALLEY.		
	Young, yellow.	Young, red.	Total.	Young, yellow.	Young, red.	Total.
Adults:						
Yellow .....	81	35	116	7	1	8
Red .....	34	80	114	2	2	4
Brown .....	1 (?)	....	1	....	....	....
Total .....	116	115	231	9	3	12

Conducting an analysis of the color-relations between parents and offspring, to ascertain whether a Mendelian order of inheritance is followed, the characters in question, as well as the problems, are precisely the same as in the case of *P. o. rubescens*. We may ignore the few *phæa* individuals, and deal only with the numerous yellow and red members of the Aoua colony. In the general population, the former amount to 304 out of 645, or 47.1 per cent, and the latter to 341, or 52.8 per cent; these are basic data.

Proceeding first on the assumption that the red color is dominant, the gravid adults with distinguishable young are classified as follows:

- (1) Red adults: red young, 51; red and yellow young, 12; yellow young, 19=82
- (2) Yellow adults: red young, 25; red and yellow young, 5; yellow young, 60=90

The yellow parents would have mated with DD, DR, and RR snails according to the chance possibilities, of which the last is known, inasmuch as the group assumed to be RR—viz, those of (2)—constitute 47 per cent of the population at large. Hence the combination  $RR \times RR$  would occur in 47 per cent of the 90 cases, or 42, and these would bear yellow young only. Actually, however, there are 60, and hence the excess over 42, or 18, comprises the  $RR \times DR$  cases where too few offspring appear to represent both of the expected kinds. Transferring the 18 such cases to the middle class, and a similar proportionate number ( $\frac{3}{10}$  of 25 or 7.5) from the first to the second group, for similar reasons, (2) becomes

- (3) Yellow adults: red young, 17.5; red and yellow young, 30.5; yellow young, 42=90

and the proportionate numbers of DD, DR, and RR snails thus become defined.

Testing the correspondence of the expected numbers with the empirical observations for the class of red adults of (1), it appears that the DD members amount to 30, whose young would be red in color whatever their mates. The remaining 52 DR individuals would have DD mates in 18 instances, and would also bear red young only, while the remaining 42 would theoretically produce both kinds of young. The expected figures would thus be:

- (4) Red adults: red young, 40; red and yellow young, 42 = 82

Empirically the numbers are, respectively, 51:31 = 82; but when the second and third classes of (1) are combined, and the figure for the first class is reduced by the  $\frac{3}{10}$  to be transferred to the second group, the figures become 36:46, which differ from expectation by 4 out of 82 cases, or 4.8 per cent.

Proceeding on the alternative assumption, namely, that the yellow is the dominant color, we classify gravid adults with young according to their contents, each parent taken once, with the following results:

- (5) Yellow adults: yellow young only, 60; yellow and red young, 5; red young only, 25 = 90  
(6) Red adults: yellow young only, 19; yellow and red young, 12; red young only, 51 = 82

Beginning with the red series (6), we would expect their mates to have been RR in 53 per cent of the cases, or 43.46, with red young only as their products. Empirically, however, there are 51 such gravid parents, and hence the surplus over 43.5, or 7.5, are individuals mated with DR yellow snails, where yellow young do not appear among the few young produced. Therefore, 7.5 is to be subtracted from the third class of (6) and added to the middle one. A further correction is necessary on account of the presence in the first class of individuals, RR in composition, that have mated with DR, but whose potential red young do not appear; as a measure for the amount of reduction we have the relation of 7.5 out of 51 in the analysis of the third class, or a proportion of 14.7 per cent, equal to about 3 individuals. Making this adjustment, (6) becomes:

- (7) Red adults: yellow young, 16; yellow and red young, 23; red young, 43 = 82

These are the proportionate numbers of RR adults which have mated with DD, DR, and RR, respectively, and at the same time the relative numbers of the three gametic classes.

Now we may proceed to analyze the yellow adults of (5) to test the probability of the results obtained from the contrasted class. The second and third groups are to be combined because yellow as well as red young are to be expected if yellow is a dominant character. Out of the total of 90 cases, DD yellows amount to 37, if the proportions of (7) are correct; whether mated with DD, DR and RR, their young would be yellow only. Of the remaining 53 which are DR, we would have DD mates and yellow young only in 10 cases, while in 43 cases the mates would be DR and RR, with both kinds of young among the offspring. Combining these figures, expectations would be:

- (8) Yellow adults: yellow young, 47; yellow and red young, 43 = 90

Actually, when the combination and corrections of (5) have been made, the figures are 51 and 39, respectively, thus disclosing a discrepancy of 4 out of 90 cases, or 4.4 per cent.

The foregoing analysis does not lead to a decisive conclusion regarding the dominance or recessiveness of the red color, although the probability of a Mendelian order of inheritance is indicated. It is by analogy with the case of *P. o. rubescens* and with that of *Helix* as investigated experimentally by Lang, that the red color factor would be regarded as the dominant member of the pair.

#### NORTHERN CRASSA SERIES—ATEHI TO PUNARUU VALLEYS.

In the three valleys to the northward of the small area occupied by *crassa occidentalis*, the *otaheitana* colonies display the principal features of the typical *crassa* found to the south. Atehi (which is next to Papehū) and Maruapoo are short, deep valleys of the fourth order of size, while the third area is Punaruu, a great element of the first order. Here, then, we find one and the same variety in three valleys, whereas in the case of *P. nodosa* each topographical element is inhabited by a distinct primary variety, viz, *nodosa exigua*, *nodosa læva*, and *nodosa composita*. The lack of differentiation in the one case and its existence in the other case can scarcely be referred to identical environmental conditions.

The three colonies of this northern series are made up of *phæa* and *cestata* color-classes, in absolute and relative numbers that have been given earlier in table 233. In Atehi, the former class is made up of *confluens* in the main (plate 33, figs. 50 to 53) although some intergrading *striata* occur; two exceptional decorticated examples were found, one of which is illustrated in plate 33, figure 50. In Maruapoo also the *striata* shells were few, and were not sharply separated from the *confluens* class (plate 33, figs. 59 and 60). The third colony, that of Punaruu, comprised a large number of very characteristic *striata* (plate 33, figs. 61 to 64), which as before gradually merged into *confluens*. Shells of the *cestata* class greatly preponderate in Atehi (plate 33, figs. 54 to 58), but form a minority in the other two valleys (plate 34, figs. 1 and 2). In general the "median" band is more clearly marked than in the *crassa* of the southern series, and the sutural and basal bands are sometimes developed so as to render the pattern somewhat like that of *sinistralis* banded examples.

In statistical respects (table 234) the associations differ from one another in various ways, in different measures; the details are sufficiently described by the numerical data. When the plain and banded classes are compared the relations existing in one case are reversed in another, without any consistency.

The several subdivisions of the Punaruu colony, taken in different years from the lower, middle, and upper parts of the inhabited area, are not identical in their morphology. The most interior specimens are not much larger than the typical *crassa*, and hence the statistical results do not accord with Garrett's statement that "far above the range of *nodosa* in Punaruu, the *otaheitana* shells are similar to, but larger than, *crassa*." Possibly at the very head of the valley they may be, but my own explorations could not be prosecuted beyond a distance of 5 miles from the coast.

The figures for fecundity (table 235) need no special comment, except that the 1906 series from Punaruu shows a lower rate than the collection taken during the alternative time of the year.

TABLE 234.—*Partula otaheitana crassa*, northern series. Atehi, Maruapoo, and Punaruu Valleys.

MEAN VALUE.									
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index <sup>1</sup>
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
		mm.	mm.	p. ct.	mm.	mm.	p. ct.	p. ct.	
Atehi, plain.....	130	17.1707 ± .0530	9.9661 ± .0243	58.0534 ± .1480	8.8631 ± .0257	6.8708 ± .0205	77.4153 ± .1408	51.5708 ± .1111	1.6708 ± .0518
banded.....	278	17.2633 ± .0348	10.0036 ± .0183	57.9028 ± .0865	8.9194 ± .0182	6.9252 ± .0149	77.5359 ± .1057	51.6511 ± .0699	1.5655 ± .0333
Atehi, all.....	408	17.2338 ± .0291	9.9917 ± .0147	57.9510 ± .0755	8.9015 ± .0149	6.9078 ± .0121	77.4975 ± .0849	51.6255 ± .0593	1.5909 ± .0280
Maruapoo, plain.....	116	17.0595 ± .0422	9.9586 ± .0238	58.2327 ± .1458	8.7741 ± .0298	6.8518 ± .0201	77.8103 ± .1546	51.3193 ± .1099	3.0339 ± .0411
banded....	17	16.6206 ± .0899	9.9000 ± .0420	59.6764 ± .3424	8.7118 ± .0555	6.8765 ± .0461	78.7941 ± .2792	52.5588 ± .3097	2.8236 ± .1155
Maruapoo, all.....	133	17.0034 ± .0390	9.9511 ± .0215	58.4173 ± .1374	8.7662 ± .0221	6.8549 ± .0185	77.9361 ± .1408	51.4775 ± .1065	3.0074 ± .0391
Punaru, plain, 1906..	156	16.8616 ± .0457	9.9141 ± .0244	58.7628 ± .1342	8.8821 ± .0253	6.6513 ± .0201	74.7308 ± .1635	52.6218 ± .0944	2.7378 ± .0394
banded, 1906..	1	16.85	9.70	58.50	9.10	6.70	73.50	53.50	3.0000 ± .0
plain, 1908..	163	17.4849 ± .0398	10.1527 ± .0290	57.9785 ± .1393	9.2484 ± .0230	6.8338 ± .0194	73.8804 ± .1500	52.8067 ± .0973	2.8012 ± .0355
banded, 1908..	5	17.7500 ± .2158	10.4200 ± .1588	58.7000 ± .9986	9.4600 ± .1170	7.1000 ± .0853	74.9000 ± .4901	53.5000 ± .3304	2.6000 ± .2413
plain, 1909..	188	17.2010 ± .0466	9.9236 ± .0251	57.6595 ± .1275	9.0882 ± .0242	6.7224 ± .0205	73.8085 ± .1448	52.7681 ± .0970	2.8301 ± .0287
banded, 1909..	9	16.8500 ± .1770	9.7889 ± .0640	57.9444 ± .4510	8.9000 ± .0924	6.6112 ± .0374	74.7222 ± .4831	52.6111 ± .4165	2.6000 ± .1955
Punaru, all, 1906....	157	16.8602 ± .0454	9.9127 ± .0242	58.7611 ± .1334	8.8841 ± .0251	6.6516 ± .0199	74.7229 ± .1625	52.6274 ± .0939	2.7394 ± .0392
1908....	168	17.4928 ± .0394	10.1607 ± .0286	58.0000 ± .1385	9.2547 ± .0236	6.8417 ± .0191	73.9107 ± .1465	52.8273 ± .0951	2.7955 ± .0352
1909....	197	17.1850 ± .0453	9.9172 ± .0241	57.6725 ± .1234	9.0797 ± .0235	6.7173 ± .0195	73.8503 ± .1402	52.7589 ± .0945	2.8195 ± .0285
Punaru, all.....	522	17.1868 ± .0263	9.9943 ± .0152	58.1054 ± .0771	9.0771 ± .0144	6.7375 ± .0115	74.1322 ± .0869	52.7414 ± .0549	2.7882 ± .0196
STANDARD DEVIATION.									
Atehi, plain.....	130	0.8963 ± .0375	0.4109 ± .0172	2.5026 ± .1046	0.4345 ± .0182	0.3465 ± .0145	2.3808 ± .0995	1.8786 ± .0785	0.8766 ± .0366
banded.....	278	.8594 ± .0246	.4525 ± .0128	2.1398 ± .0611	.4501 ± .0129	.3690 ± .0105	2.6127 ± .0747	1.7275 ± .0494	.8313 ± .0235
Atehi, all.....	408	.8724 ± .0206	.4400 ± .0104	2.2627 ± .0534	.4460 ± .0105	.3629 ± .0086	2.5423 ± .0600	1.7767 ± .0419	.8435 ± .0198
Maruapoo, plain.....	116	.6734 ± .0298	.3806 ± .0168	2.3281 ± .1031	.4756 ± .0211	.3212 ± .0142	2.4685 ± .1093	1.7550 ± .0777	.6629 ± .0290
banded....	17	.5496 ± .0635	.2566 ± .0297	2.0930 ± .2421	.3394 ± .0392	.2818 ± .0326	1.7069 ± .1974	1.8933 ± .2190	.7059 ± .0817
Maruapoo, all.....	133	.6669 ± .0276	.3676 ± .0152	2.3493 ± .0971	.3945 ± .0163	.3166 ± .0131	2.4072 ± .0995	1.8208 ± .0753	.6721 ± .0276
Punaru, plain, 1906..	156	.8463 ± .0323	.4518 ± .0172	2.4861 ± .0949	.4681 ± .0179	.3715 ± .0142	3.0273 ± .1136	1.7480 ± .0667	.7479 ± .0278
banded, 1906..	1	.....	.....	.....	.....	.....	.....	.....	.0
plain, 1908..	163	.7544 ± .0281	.5489 ± .0205	2.6361 ± .0985	.4356 ± .0162	.3674 ± .0137	2.8397 ± .1061	1.8413 ± .0688	.6893 ± .0251
banded, 1908..	5	.7155 ± .1526	.5264 ± .1123	3.3106 ± .7061	.3878 ± .0827	.2828 ± .0603	1.6248 ± .3465	1.0954 ± .2336	.8000 ± .1706
plain, 1909..	188	.9478 ± .0329	.5106 ± .0177	2.5921 ± .0901	.4925 ± .0171	.4168 ± .0145	2.9428 ± .1024	1.9712 ± .0686	.6116 ± .0203
banded, 1909..	9	.7874 ± .1251	.2846 ± .0452	2.0061 ± .3189	.4109 ± .0653	.1664 ± .0264	2.1487 ± .3416	1.8526 ± .2945	.9165 ± .1382
Punaru, all, 1906....	157	.8433 ± .0321	.4507 ± .0171	2.4783 ± .0943	.4673 ± .0177	.3691 ± .0141	3.0192 ± .1149	1.7438 ± .0664	.7459 ± .0249
1908....	168	.7566 ± .0278	.5506 ± .0202	2.6614 ± .0979	.4530 ± .0167	.3679 ± .0135	2.8155 ± .1036	1.8273 ± .0672	.6935 ± .0277
1909....	197	.9439 ± .0320	.5012 ± .0170	2.5689 ± .0872	.4886 ± .0166	.4069 ± .0138	2.9174 ± .0991	1.9664 ± .0668	.6308 ± .0201
Punaru, all.....	522	.8925 ± .0186	.5164 ± .0107	2.6111 ± .0545	.4881 ± .0102	.3910 ± .0081	2.9424 ± .0614	1.8588 ± .0388	.6871 ± .0138

<sup>1</sup>The numbers are: Atehi, 130, 283, 413; Maruapoo, 118, 17, 135; Punaru, 164, 1, 171, 5, 206, 10, 165, 176, 216, 557.

The inheritance of the color-patterns (table 236) is such as to render the relative numbers sensibly equivalent in the groups of parents and offspring. The colonies seem to be stable so far as their color-composition is concerned, if the facts are correctly indicated by the recorded observations.

TABLE 235.—*Partula otaheitana crassa*, northern series. Atehi, Maruapoo and Punaruu Valleys. Fecundity.

	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.
Atehi, plain, 1907.....	129	84	65.1	138	23	161	1.92	1.25
banded, 1907.....	281	189	67.3	320	85	405	2.14	1.44
Atehi, all, 1907.....	410	273	66.6	458	108	566	2.07	1.38
Maruapoo, plain, 1908.....	106	63	59.4	94	22	116	1.84	1.09
banded, 1908.....	16	6	37.5	11	3	14	2.33	0.87
Maruapoo, all, 1908.....	122	69	56.6	105	25	130	1.88	1.07
Punaruu, plain, 1906.....	144	75	52.1	34	88	122	1.63	0.85
banded, 1906.....	1	1	100	0	1	1	1.00	1.00
plain, 1908.....	163	130	79.8	226	95	321	2.47	1.97
banded, 1908.....	5	5	100	9	4	13	2.60	2.60
plain, 1909.....	196	154	78.6	252	139	391	2.54	1.99
banded, 1909.....	10	9	90.0	17	4	21	2.33	2.10
Punaruu, all, 1906.....	145	76	52.4	34	89	123	1.62	0.85
1908.....	168	135	80.4	235	99	334	2.47	1.99
1909.....	206	163	79.1	269	143	412	2.53	2.00

TABLE 236.—*Partula otaheitana crassa*, northern series.

HEREDITY, PUNARUU VALLEY.												
	Young, plain.				Young, banded.				Total.			
	1906.	1908.	1909.	Total.	1906.	1908.	1909.	Total.	1906.	1908.	1909.	Total.
Adults, plain, 1906.....	88	..	...	322	{ 0	..	..	0	{ 88	..	...	322
1908.....	..	95	...		{ ..	0	..		{ ..	95	...	
1909.....	..	..	139		{ ..	..	0		{ ..	..	139	
Adults, banded, 1906.....	0	..	...	5	{ 1	..	..	4	{ 1	..	...	9
1908.....	..	1	...		{ ..	3	..		{ ..	4	...	
1909.....	..	..	4		{ ..	..	0		{ ..	..	4	
Total, 1906.....	88	..	...	327	{ 1	..	..	4	{ 89	..	...	331
1908.....	..	96	...		{ ..	3	..		{ ..	99	...	
1909.....	..	..	141		{ ..	..	0		{ ..	..	143	

HEREDITY, MARUAPOO VALLEY.				HEREDITY, ATEHI VALLEY.		
	Young, plain.	Young, banded.	Total.	Young, plain.	Young, banded.	Total.
Adults:						
Plain.....	22	0	22	15	8	23
Banded...	2	1	3	14	71	85
Total.....	24	1	25	29	79	108

In the case of the Atehi series, it is possible to conduct an inquiry into the Mendelian nature and behavior of the plain and banded color-characters. The unbanded adults amount to 31.5 per cent and the contrasted snails to 68.5 per cent of the whole population. When the gravid parents with distinguishable young are classified, they group themselves as follows:

Plain adults: plain young, 9; both kinds, 4; banded young, 4..... 17  
 Banded adults: plain young, 8; both kinds, 6; banded young, 51..... 65



The data are scanty, but the analysis is interesting because the characters are the same that were investigated in the independent cases of *affinis* and *sinistrorsa*.

First assuming that banding is recessive, the numbers of DD, DR, and RR come out as 7 : 13 : 45. When the test is carried out in the case of the plain snails, the expected numbers are 7 : 10, and the empirical numbers are 8 : 9 for the two groups of parents with plain young only and parents with both kinds of young. The difference amounts to 5.9 per cent of the cases involved.

Under the contrary assumption, the proportion of the three genetic classes would be 2 : 10 : 5, which seems more natural, but the independent test gives a departure of observation from theory to the extent of 16.9 per cent of the cases. Were it not for the clear case of *affinis* and the probably similar relation in the *sinistrorsa* series analyzed, the present result might not be significant as to the reality of a Mendelian nature of this phenomena.

#### PARTULA OTAHEITANA CRASSA ABERRANS SUBVAR. NOV.—TAAPUNA VALLEY.

Taapuna is the most northern valley of the western sector that is suitable as a habitation for *Partula*. It is true that two or three small gullies occur in the interval between this valley and Tahaa Point, at the extreme northeast, but snails are either absent from them or very infrequently found. Taapuna is inhabited by *otaheitana* snails belonging to the present primary variety, *crassa*, but the colony exhibits several remarkable features that justify its recognition as a distinct section of this division on the same plane with *occidentalis*; the quaternary term *aberrans* is given to it for the sake of brevity. Only a few snails were taken in 1906 (17 in all), but in 1909, 208 adults were secured, mainly from the interior part of the valley. Here *P. nodosa* is represented by a flourishing association of the variety *composita* similar to that of Punaruu—a fact of some interest in view of the difference between the *otaheitana crassa* of the latter valley and the peculiar colony of Taapuna.

The colony as a whole is characterized, among other things, by its color-composition. Disregarding certain specimens that were decolorized by imperfect preservative, there remain 180 adults, to be classified as follows:

cestata, lightly banded.....	4 = 2.2 per cent.
Plain, light (yellowish).....	20 = 11.1 per cent.
Plain, medium (yellow-brown, red-brown).....	73 = 40.5 per cent.
Plain, dark (dark brown).....	83 = 46.1 per cent.

The shells of the first-named class are much like their correspondents of Punaruu in the lightness of the revolving band (plate 34, figs. 12 and 13). The light "plain" shells (plate 34, figs. 3 to 5) are somewhat similar to the "yellow" class of *crassa occidentalis* from Papehuc and Aoua, not only in the richer ground-color, but in its smoothness and lack of strigations as well. The class called "medium" (plate 34, figs. 6 to 8) comprises a novel color-form not hitherto encountered; here the ground tint is an even red-brown or an even yellowish-brown, entirely devoid of strigation. Finally the "dark" class comprises a few fine specimens corresponding to *phæa confluent* of typical *crassa* colonies, but the more numerous shells display a rich, even shade of brown, sometimes of a very deep hue (plate 34, figs. 9 to 11); these



last are similar in color to certain large *sinistrorsa* shells of the far southeast that were distinguished as the color-form *phæa solida*. In brief, the "dark" class resembles *phæa solida* of southward colonies, the "light class" is like one of the *occidentalis* color-forms, while the "medium" class is unique, saving for the presence of a reddish tone in many cases, which simulates the color of the "red" *occidentalis* group.

When the statistics relating to the standard characters are arrayed (table 237), it appears, first, that the small group from the lower level, taken in 1906, is composed of larger and slightly stouter shells, with apertures of relatively greater length; secondly, when the colony as a whole is compared with *crassa* of Punaruu, its members prove to be larger and wider in the measures of the whole shell and also of the aperture; in the proportionate figures, however, the relations are about the same. The tooth is well-developed as a colonial character. In the third place, the few banded individuals are aberrant, as would be expected.

TABLE 237.—*Partula otaheitana crassa aberrans*, Taapuna Valley.

MEAN VALUE.									
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index. <sup>1</sup>
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
		<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>p. ct.</i>	
Plain, 1906...	14	18.4357 ± .1725	10.6857 ± .0823	58.0000 ± .3389	9.9285 ± .0923	7.4143 ± .0573	74.5714 ± .3438	53.6428 ± .1649	2.0714 ± .1861
Banded, 1906...	1	17.75	10.30	57.50	9.30	7.30	79.50	52.50	3.0
Plain, 1909...	201	18.0335 ± .0393	10.4562 ± .0206	57.8880 ± .1050	9.6432 ± .0213	7.1268 ± .0179	73.7737 ± .1355	53.3905 ± .0878	2.4510 ± .0449
Banded, 1909...	3	18.3500 ± .4371	10.7666 ± .0971	58.8333 ± .8002	9.9666 ± .0971	7.5666 ± .0367	75.8333 ± .8002	54.1666 ± .9714	2.0000 ± .3179
All, 1906.....	15	18.3900 ± .1548	10.6600 ± .0960	57.9666 ± .2822	9.8866 ± .0904	7.4066 ± .0538	74.9000 ± .3857	53.5666 ± .1618	2.1334 ± .1784
All, 1909.....	204	18.0382 ± .0393	10.4607 ± .0204	57.9019 ± .1043	9.6480 ± .0209	7.1333 ± .0178	73.8089 ± .1342	53.4019 ± .0878	2.4445 ± .0448
All.....	219	18.0623 ± .0416	10.4744 ± .0199	57.9064 ± .0995	9.6644 ± .0207	7.1521 ± .0173	73.8790 ± .1285	53.4132 ± .0826	2.4234 ± .0423
STANDARD DEVIATION.									
Plain, 1906...	14	0.9568 ± .1220	0.4565 ± .0582	1.8803 ± .2396	0.5120 ± .0653	0.3181 ± .0405	1.9073 ± .2431	0.9148 ± .1166	1.0326 ± .1316
Banded, 1906...	1	.....	.....	.....	.....	.....	.....	.....	.....
Plain, 1909...	201	.8262 ± .0278	.4335 ± .0145	2.2077 ± .0742	.4474 ± .0151	.3763 ± .0126	2.8477 ± .0958	1.8469 ± .0621	.9510 ± .0317
Banded, 1909...	3	1.1225 ± .3091	.2494 ± .0687	2.0548 ± .5658	.2494 ± .0687	.0942 ± .0259	1.2472 ± .3434	2.4944 ± .6869	.8165 ± .2248
All, 1906...	15	.8890 ± .1094	.5511 ± .0679	1.6202 ± .1995	.5189 ± .0639	.3088 ± .0380	2.2151 ± .2727	.9290 ± .1144	1.0242 ± .1261
All, 1909.....	204	.8322 ± .0278	.4330 ± .0144	2.2085 ± .0737	.4433 ± .0148	.3774 ± .0126	2.8427 ± .0949	1.8604 ± .0621	.9560 ± .0317
All.....	219	.9123 ± .0294	.4372 ± .0141	2.1842 ± .0703	.4548 ± .0146	.3794 ± .0122	2.8191 ± .0909	1.8124 ± .0584	.9352 ± .0299

<sup>1</sup>The numbers are, respectively, 14, 1; 204, 3; 15, 207; 222.

Still another distinctive feature of the colony is to be noted. The eggs of gravid snails are elongated to a remarkable degree, as compared with those of all other varieties of *Partula otaheitana*. By itself this would not be significant, but it occurs in correlation with a characteristic color-composition and a fuller shell-development.

Fecundity (table 238) proves to be normal for the respective period of the year in both annual series.

Passing to heredity (table 238) it appears that no young were found with bands; in view of the lightness of the stripe, even in the adult, it must escape detection in the very few cases of sporadic *cestata* young. As far as the "plain" class is concerned, it is significant that the proportionate numbers referable to the three color-groups are much the same in parental and offspring series. On the basis of the facts as observed and recorded, the color-composition of the prevalent unbanded class seems to be stable from year to year.

TABLE 238.—*Partula otaheitana crassa aberrans*, Taapuna Valley.

FECUNDITY.								
	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.
1906, plain.....	9	4	44.4	1	3	4	1.00	0.44
1909, plain.....	178	145	81.5	214	136	350	2.41	1.97
1909, banded.....	3	2	66.6	3	2	5	2.50	1.67
1909, all.....	181	147	81.2	217	138	355	2.41	1.96

HEREDITY.				
	Young, plain.			Total.
	Light.	Medium.	Dark.	
Adults:				
Plain, light.....	10	3	..	13
medium.....	10	26	20	56
dark.....	6	21	40	67
Banded.....	..	1	1	2
Total.....	26	51	61	138
	138			

## SUMMARY AND CONCLUSION.

I. *Partula otaheitana crassa* is the third member of a southern and western series of primary varieties composed mainly of sinistral individuals with brown shells, sometimes bearing revolving bands. Virtually all of its characters are displayed by some of the members of the basic stock existing in Fautaua Valley. Its affinities with *otaheitana sinistralis* are closer than with *otaheitana sinistrorsa*, in correspondence with the geographical relations of their areas.

II. The primary variety is differentiated more clearly than are its near relatives into subordinate groups, two of which deserve distinctive names. The fundamental *crassa* stock is interrupted in its range by a wedge including two valleys that are inhabited by the peculiar *crassa occidentalis*, while again at its northern limit it appears in the novel colony of *aberrans*, distinguished by such diverse features as its color-composition, size of the shell, and form of the egg. The boundaries that mark the subsidiary areas of these secondary divisions do not correspond with those which delimit the spheres of the primary varieties of *Partula nodosa*, a species that inhabits seven of the same valleys.

TABLE 24I. *Partula otaheitana crassa*. Progressive colonial variation as regards range and mean value.

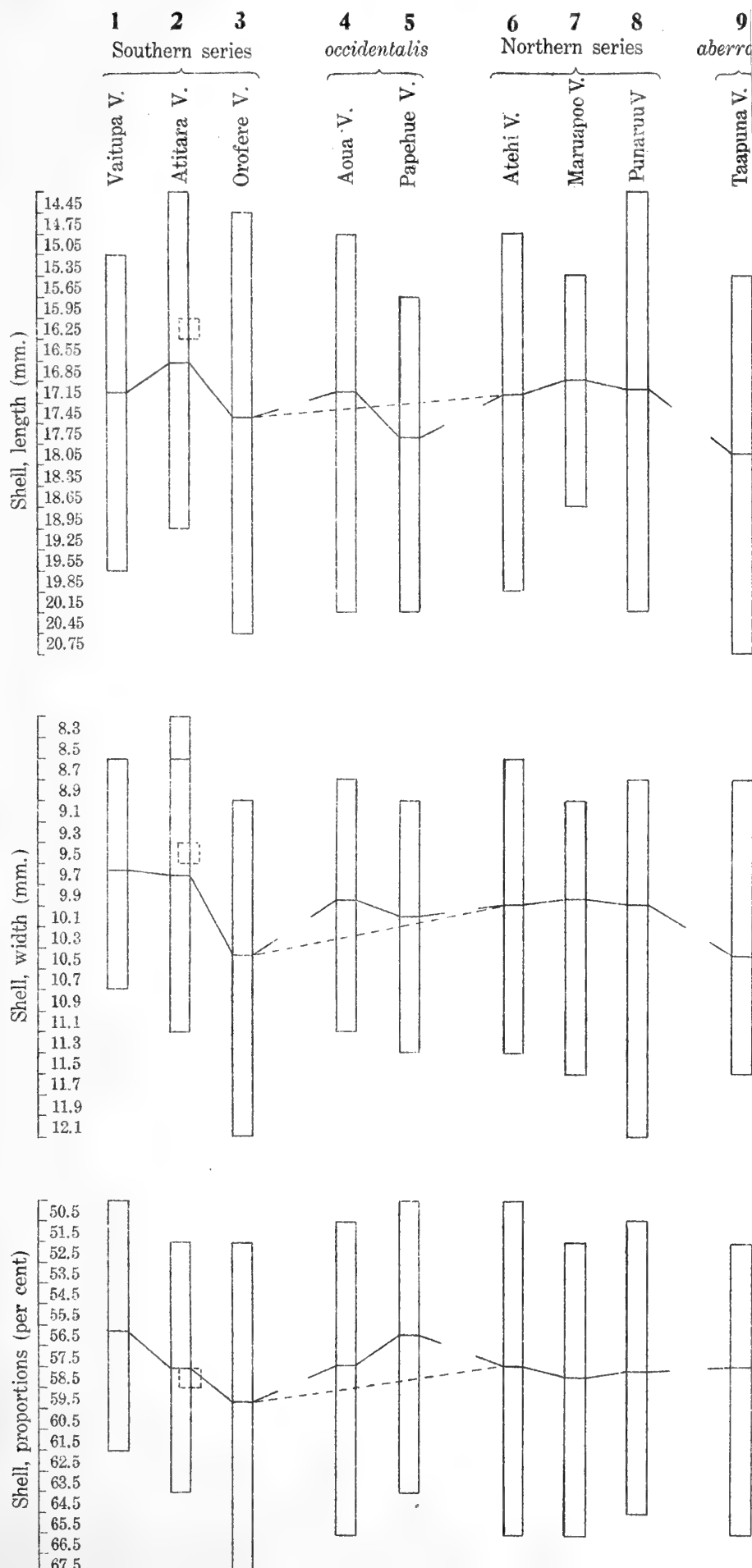
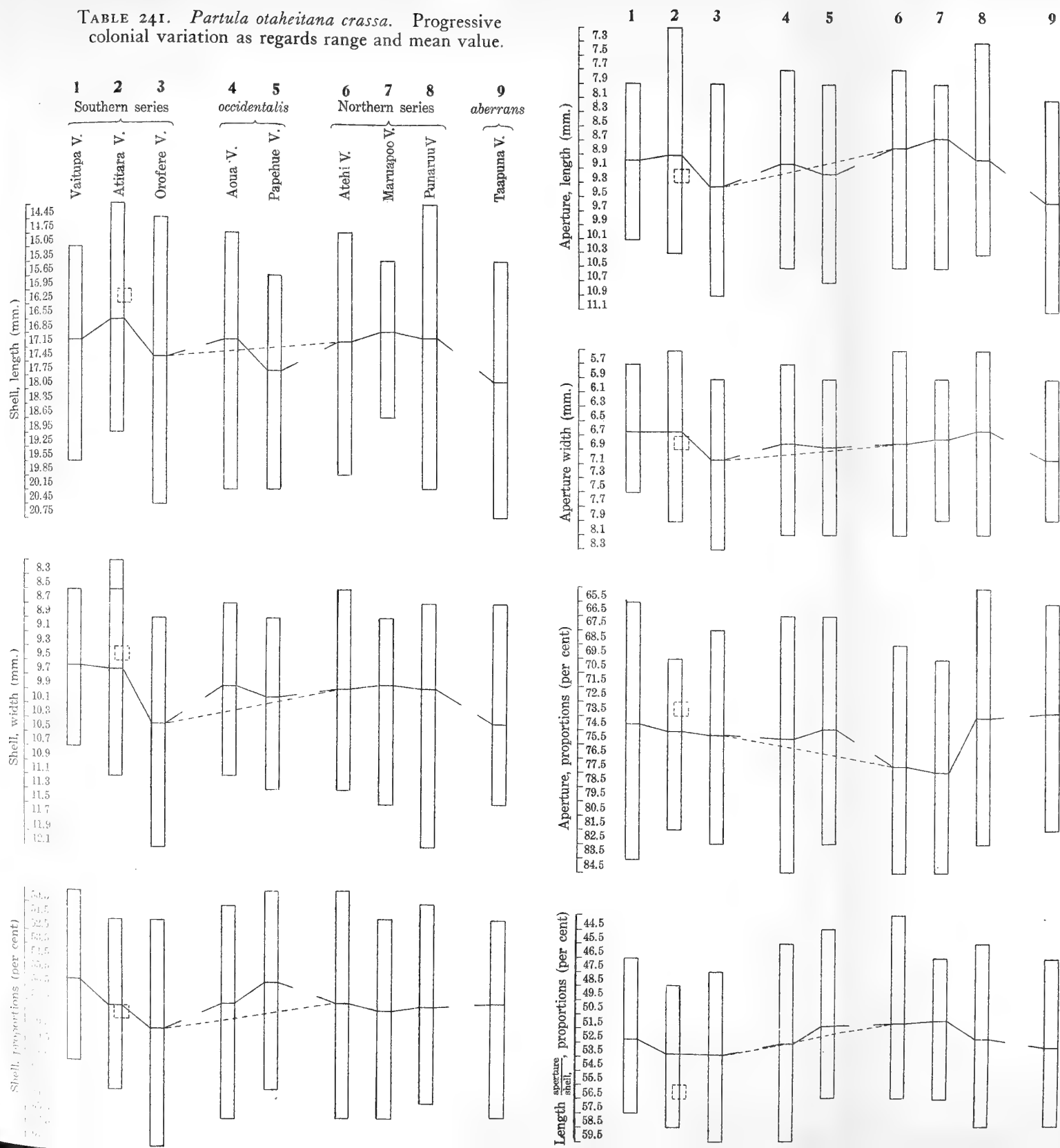




TABLE 241. *Partula otaheitana crassa*. Progressive colonial variation as regards range and mean value.





III. The colonial characters are manifested in (a) relative numbers of unbanded and cestata individuals; (b) differentiation in the phæa class of typical crassa; (c) in the presence of red and yellow classes; (d) in the statistical determinations. The facts in the last-named connection are presented anew in summary (tables 239 and 240) and in graphic form (table 241).

TABLE 239.—*Partula otaheitana crassa*. Summary statistical description. Mean value.

Group and valley.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index. <sup>1</sup>
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
[ <i>sinistralis</i> ]:		mm.	mm.	p. ct.	mm.	mm.	p. ct.	p. ct.	
Vaipuarii.....	176	18.6244 ± .0419	10.5795 ± .0219	56.7102 ± .1094	9.6341 ± .0234	7.2568 ± .0185	75.2670 ± .1306	51.6022 ± .0877	1.0444 ± .0128
Southern <i>crassa</i> :									
Vaitupa.....	317	17.1661 ± .0274	9.6785 ± .0135	56.3139 ± .0800	9.0697 ± .0151	6.7694 ± .0121	74.5820 ± .0981	52.7461 ± .0666	2.3739 ± .0372
Atitara.....	153	16.7206 ± .0426	9.7131 ± .0214	58.0163 ± .1196	9.0176 ± .0251	6.7771 ± .0193	75.0425 ± .1247	53.8464 ± .1066	2.7386 ± .0440
Orofere.....	196	17.5388 ± .0490	10.4714 ± .0303	59.6327 ± .1303	9.4684 ± .0271	7.1418 ± .0220	75.3469 ± .1252	53.9184 ± .0965	3.2842 ± .0402
<i>crassa occidentalis</i> :									
Aoua.....	635	17.1609 ± .0230	9.9469 ± .0116	57.8827 ± .0632	9.1315 ± .0124	6.9157 ± .0097	75.6339 ± .0689	53.1078 ± .0519	2.7600 ± .0188
Papehue.....	137	17.8354 ± .0503	10.1088 ± .0262	56.4489 ± .1438	9.2693 ± .0308	6.9555 ± .0218	74.9599 ± .1561	51.9015 ± .1139	1.6409 ± .0437
Northern <i>crassa</i> :									
Atehi.....	408	17.2338 ± .0291	9.9917 ± .0147	57.9510 ± .0755	8.9015 ± .0149	6.9078 ± .0121	77.4975 ± .0849	51.6255 ± .0593	1.5909 ± .0280
Maruapoo.....	133	17.0034 ± .0390	9.9511 ± .0215	58.4173 ± .1374	8.7662 ± .0221	6.8549 ± .0185	77.9361 ± .1408	51.4775 ± .1065	3.0074 ± .0391
Punaruu.....	522	17.1868 ± .0263	9.9943 ± .0152	58.1054 ± .0771	9.0771 ± .0144	6.7375 ± .0115	74.1322 ± .0869	52.7414 ± .0549	2.7882 ± .0196
<i>crassa aberrans</i> :									
Taapuna.....	219	18.0623 ± .0416	10.4744 ± .0199	57.9064 ± .0995	9.6644 ± .0207	7.1521 ± .0173	73.8790 ± .1285	53.4132 ± .0826	2.4234 ± .0423

<sup>1</sup>The numbers are larger in nearly all cases.

TABLE 240.—*Partula otaheitana crassa*. Progressive comparison of colonies. Differences in mean value.

Group and valley.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index.
	Length.	Width.	Proportions.	Length.	Width.	Proportions.		
<i>sinistralis</i> :								
Vaipuarii.....	mm.	mm.	p. ct.	mm.	mm.	p. ct.	p. ct.	
Southern <i>crassa</i> :	-1.4583 ± .0501	-0.9010 ± .0257	-0.3963 ± .1355	-0.5644 ± .0236	-0.0487 ± .0221	-0.6850 ± .1633	+1.1439 ± .1101	+1.3295 ± .0393
Vaitupa.....	- .4455 ± .0506	[+.0346 ± .0253]	+1.7024 ± .1439	[-.0521 ± .0293]	[+.0077 ± .0228]	+ .4605 ± .1586	+1.1003 ± .1257	+ .3647 ± .0576
Atitara.....	+ .8182 ± .0649	+ .7583 ± .0371	+1.6164 ± .1768	+ .4508 ± .0369	+ .3647 ± .0293	[+ .3044 ± .1767]	[+ .0720 ± .1438]	+ .5456 ± .0596
Orofero.....	- .3779 ± .0689	- .5245 ± .0324	-1.7500 ± .1448	- .3369 ± .0298	- .2261 ± .0240	+ .2870 ± .1429	- .8106 ± .1109	- .5242 ± .0444
<i>crassa occidentalis</i> :								
Aoua.....	+ .6745 ± .0553	+ .1619 ± .0287	-1.4338 ± .1570	+ .1378 ± .0332	[+.0398 ± .0239]	- .6740 ± .2116	-1.2063 ± .1263	-1.1191 ± .0476
Papehue.....	- .6016 ± .0581	- .1171 ± .0300	+1.5021 ± .1624	- .3678 ± .0342	[-.0477 ± .0249]	+2.5376 ± .1777	- .2760 ± .1284	[- .0500 ± .0519]
Northern <i>crassa</i> :								
Atehi.....	- .2304 ± .0487	[-.0406 ± .0260]	+ .4663 ± .1568	- .1353 ± .0267	- .0529 ± .0221	+ .4386 ± .1644	[- .1480 ± .1219]	+1.4165 ± .0481
Maruapoo.....	+ .1834 ± .0470	[+.0432 ± .0263]	[- .3119 ± .1575]	+ .3109 ± .0264	- .1174 ± .0218	-3.8039 ± .1654	+1.2639 ± .1198	- .2195 ± .0437
Punaruu.....	+ .8755 ± .0492	+ .4801 ± .0250	[- .1990 ± .1259]	+ .5873 ± .0252	+ .4146 ± .0208	[- .2532 ± .1551]	+ .6718 ± .0992	- .3648 ± .0466
<i>crassa aberrans</i> :								
Taapuna.....								

IV. Combining the figures for all valleys, the primary variety as a whole may be described for comparison with other divisions of *Partula otaheitana*. As before, the combination may be effected in two ways: by uniting all shells into one series of variates, and by averaging the several valley types (table 242). Each series of figures has a definite biological significance.

TABLE 242.—*Partula otaheitana crassa*. Collective description. 2,720 sinistral shells.

Character.	Mean value.		Standard deviation.	
	Combined series.	Average of valley types.	Combined series.	Average of valley types.
Shell length, mm. ....	17.2787 ± .0117	17.3231	0.9081 ± .0083	0.8441
width, mm. ....	10.0069 ± .0066	10.0367	.5105 ± .0046	.4474
proportions, per cent. ....	57.8423 ± .0324	57.8527	2.5101 ± .0229	2.3640
Aperture length, mm. ....	9.1292 ± .0067	9.1517	.5157 ± .0047	.4670
width, mm. ....	6.8899 ± .0051	6.9124	.3931 ± .0036	.3693
proportions, per cent. ....	75.3860 ± .0379	75.4455	2.9342 ± .0268	2.6078
Length aperture ÷ length shell, proportions, per cent. . .	52.7566 ± .0260	52.7531	2.0096 ± .0184	1.8776
Tooth index <sup>1</sup> . ....	2.5122 ± .0120	2.6279	.9438 ± .0085	.8061

<sup>1</sup>N = 2,790.

## PARTULA OTAHEITANA LIGNARIA Pease.

## GENERAL CONSIDERATIONS.

The primary variety now to be described occupies the single valley of Tipaerui, which is located between Taapuna in the west quadrant and Fautaua Valley in the northern sector, and is the last connecting topographical element in the circuit of the island. The variety in question was described by Pease as a separate species, but its alliance with *otaheitana* was specifically mentioned. Although it has been confused with *Partula otaheitana affinis* it is really as distinct in morphological respects as its locality is disconnected geographically and topographically.

Nearly 1,000 adult snails (959) were taken during the several annual periods of field-work, together with over 400 adolescent individuals; 377 advanced embryonic snails and 372 eggs were dissected out of the gravid adults. This material affords an opportunity for an analysis that is particularly significant and valuable on account of the restricted habitat of *lignaria* and because of its sharply marked differences from the nearest colonies on either side.

The original description of Pease (P. Z. S. 1864, p. 671) is quoted in full:

“P(artula) t(esta) ovata, solidiuscula, dextrorsa, anguste umbilicata, sub lente minutissime transversim striata, irregulariter longitudinaliter striata; anfr. V. plano-convexis, sutura impressa; apertura rotunda-ovata, edentata, labro rotundatim incrassato; castaneo-fusca irregulariter longitudinaliter strigata, interdum omnino rufo-fusca. Long. 18, diam. 10 mill.

“*Var* Fascia unica nigro-fusca cingulata, seu omnino flavide fusca.

“The tubercular tooth on the wall of the aperture is seldom wanting, and there is generally a slight angle in the outer lip at its junction with the body whorl. It is allied to *P. tahitiana* [*otaheitana*]; the latter, however, is more elongate, and both dextral and sinistral; it is more varied in its colors, and the lip is usually rosaceous.”

Garrett's important statements (p. 48) are as follows:

“In a valley about two miles west of Fantana [Fautaua], there exists in abundance the variety (?) *lignaria* Pease, which, although described as dextral, is nevertheless very frequently sinistral. Though not attaining quite so large a size as the Fautaua shells, it differs none in shape, but is usually darker colored and more strigated, as well as exhibiting



one to three transverse reddish chestnut bands. The lip is always white, and the parietal tooth is very seldom absent. The inosculation with *otaheitana* is so complete that it can not be even separated as a well-marked variety."

Hartman always united *lignaria* with *affinis*; their alliance is real only so far as both primary varieties are referable to a parent *otaheitana* stock like that now existing in Fautaua Valley. Garrett is nearer the truth.

In 1898 Mayer collected 115 individuals of *lignaria*—all of which were dextral—together with 9 examples of *P. hyalina*. He pointed out the resemblance between banded *lignaria* shells and striped individuals taken in Pirai and Hamuta Valleys and seemed to regard such forms as identical. In describing the latter we have already given the reasons for considering them as full members of *P. otaheitana amabilis* associations, and not as close relatives of banded types found elsewhere; now, on the basis of the following study of *lignaria*, we will find further reasons for viewing the *lignaria* and *amabilis* shells with stripes as independent of one another.

Before proceeding to the analysis of the *lignaria* association, it is necessary to describe certain topographical details of Tipaerui Valley. Its mouth is about 2 statute miles west of Fautaua, as Garrett rightly states. At first it is about 0.375 of a mile in width, but as one follows its course inland its sides converge and rise to greater heights. About a mile from the coast, it is only a few score yards in width, but above this point it opens out again. Not until nearly 2 miles up is the thick undergrowth of succulent plants encountered. At about 3 miles inland, one reaches the junction of two streams, one of which comes from an easterly source on the western side of the main divide between the upper parts of Fautaua and Tipaerui. The other stream arises on the steep slopes of Mamanu Mountain, a high peak on the ridge between upper Tipaerui and Taapuna Valley. But in both cases the mountain boundaries of Tipaerui in the interior are almost sheer precipices, probably 1,500 or more feet in height, whose altitude is such that snails do not climb to their summits; hence they constitute virtually impassable barriers to migration, although the horizontal distances from Tipaerui to Fautaua and Taapuna Valleys are very short.

In 1906, during the wet season (February and March), collections were secured from the lower part of the valley along the sides of the single main stream; a point about 2 miles from the coast, at a barometric level of 750 feet, marked the limit. In 1907, during the dry season, an additional series was collected from this area, somewhat more inland, for the purpose of securing comparative statistics on fecundity. Again in 1909, at the same time of the year, a more thorough exploration was made, this time in the further interior, along the east and west forks to very nearly the limit of habitation. The branch streams unite at a barometric level of almost 800 feet; above 1,000 feet the snails are very scarce. The collections, therefore, represent the inhabitants of different sections of the whole valley, as follows: 1906 lower area, 1907 middle area, 1909 upper area, with (*a*) east fork and (*b*) west fork distinguished. Although the snails of these areas are close relatives, to be united under the designation *lignaria*, interesting differences come to light when the three collections are analyzed and compared in detail.

## THE SHELLS AND THEIR VARIATION.

The series of 1906 comprised 634 adults and 293 adolescent individuals, *all of which are dextral* (table 243). It is not until one penetrates to the higher levels that reversed shells are found, which accounts for their absence in Mayer's collection and for Garrett's opinion as to their scarcity. The shells fall into two principal classes, the *unbanded* or "plain" and the *banded*, each of which is much diversified. In the former, which was considered the more typical by Pease, five well-marked subdivisions are recognizable: (*a*) a few shells displaying a yellowish-fleshy color (plate 34, figs. 14 and 15); (*b*) shells streaked with brown upon a light yellowish or whitish background (plate 34, figs. 16 to 18); (*c*) shells with darker background and more numerous strigations (plate 34, figs. 19 to 24); (*d*) still darker individuals with more crowded strigations (plate 34, figs. 25 to 27), and (*e*) shells with a deep-brown coloration with heavy but indistinct strigations that merge into one another, thus giving an appearance closely approaching that of the *phæa confluens* members of the *sinistrorsa*, *sinistralis*, and *crassa* associations (plate 34, figs. 28 to 30). For practical purposes, (*a*) and (*b*) will be united into a group of so-called "light" shells, (*c*) will be treated by itself as a "medium" division, while (*d*) and (*e*) will be combined to form a "dark" class.

TABLE 243.—*Partula otaheitana lignaria*, Tipaerui Valley.

Series.	Adults.					Adolescents.						
	Total.	Plain.	Banded.	Per cent plain.	Per cent banded.	Total.	Plain.	Banded.	Per cent plain.	Per cent banded.		
1906, dex. . . . .	622	419	203	67.4	32.6	251	182	69	72.5	27.5		
1907, dex. . . . .	117	74	43	63.2	36.7	51	34	17	66.6	33.3		
1909, dex. . . . .	174	149	25	85.6	14.4	51	42	9	82.4	17.6		
1909, sin. . . . .	24	20	4	83.3	16.6	4	2	2	50	50		
		Plain, number.					Plain, per cent.					
		Total.	Very light.	Light.	Medium.	Dark.	Very dark.	Very light.	Light.	Medium.	Dark.	Very dark.
1906, dex. . . . .		419	2	27	290	77	23	0.5	6.4	69.2	18.3	5.5
1907, dex. . . . .		74	1	7	25	26	15	1.3	9.4	33.8	35.1	20.3
		Banded, number.					Banded, per cent.					
		Total.	Light.	Medium.	Dark.			Light.	Medium.	Dark.		
1906, dex. . . . .		203	26	149	28			12.8	73.4	13.8		
1907, dex. . . . .		43	12	23	8			27.9	53.5	18.6		

The banded shells (plate 34, figs. 31 to 40) also fall into subordinate groups of "light" (figs. 31 to 35), "medium" (figs. 36 and 37), and "dark" (figs. 38 to 40) individuals, according to the intensity and strength of the ground-color and markings, respectively. The characteristic and constant stripe is that which may be called median, although, like its counterpart in the single-banded *affinis*, it lies rather to

the left side of the morphological sagittal plane. Less distinct revolving bands occur below the suture; still less frequent, and more vague, are markings near the base of the whorl. The general pattern, then, agrees somewhat closely with that of banded *affinis* shells and with that of *otaheitana* and *amabilis* individuals from Fautaua and the neighboring valley to the east, although it must be noted that the only banded shells in Fautaua Valley were sinistral, not dextral as here.

The series of 1907 is made up of similar primary and secondary classes, whose percentage values correspond closely with those of the 1906 association; this series also was *exclusively dextral* (table 243).

TABLE 244.—*Partula otaheitana lignaria*, Tipaerui Valley. Analysis of series of 1906.

MEAN VALUE.									
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index. <sup>1</sup>
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
		<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>p. ct.</i>	
Plain, light . . . . .	29	17.8845 ± .1056	10.3759 ± .0516	58.0172 ± .2246	9.4380 ± .0422	7.4862 ± .0415	79.1552 ± .2575	52.6724 ± .2418	3.4483 ± .0777
medium . . . . .	286	17.8717 ± .0334	10.4357 ± .0173	58.3112 ± .0808	9.4637 ± .0179	7.4490 ± .0142	78.7203 ± .1007	52.8217 ± .0800	3.2896 ± .0343
dark . . . . .	97	17.8899 ± .0523	10.4918 ± .0291	58.5721 ± .1571	9.5021 ± .0287	7.5103 ± .0252	79.0257 ± .2006	53.0670 ± .1324	3.4700 ± .0535
Plain, all . . . . .	412	17.8767 ± .0276	10.4447 ± .0142	58.3519 ± .0692	9.4709 ± .0144	7.4660 ± .0119	78.8228 ± .0864	52.8689 ± .0652	3.3437 ± .0259
Banded, light . . . . .	27	18.1722 ± .0919	10.6259 ± .0374	58.3888 ± .2963	9.5222 ± .0485	7.4333 ± .0360	78.0926 ± .3338	52.2408 ± .3112	3.6296 ± .1008
medium . . . . .	146	17.9000 ± .0467	10.5041 ± .0236	58.6507 ± .1237	9.4028 ± .0232	7.4014 ± .0195	78.7876 ± .1401	52.3767 ± .0964	3.4149 ± .0444
dark . . . . .	29	17.9983 ± .1063	10.3759 ± .0516	57.5345 ± .2358	9.5207 ± .0547	7.4724 ± .0537	78.3621 ± .2477	52.8448 ± .2637	3.5172 ± .0908
Banded, all . . . . .	202	17.9505 ± .0386	10.5020 ± .0193	58.4554 ± .1051	9.4356 ± .0198	7.4158 ± .0168	78.6337 ± .1169	52.4257 ± .0899	3.4581 ± .0373
All [1906] . . . . .	614	17.9010 ± .0224	10.4635 ± .0105	58.3860 ± .0579	9.4593 ± .0117	7.4495 ± .0097	78.7606 ± .0704	52.7231 ± .0532	3.3810 ± .0213
STANDARD DEVIATION.									
Plain, light . . . . .	29	0.8433 ± .0747	0.4050 ± .0365	1.7931 ± .1588	0.3367 ± .0298	0.3319 ± .0293	2.0557 ± .1821	1.9310 ± .1710	0.6207 ± .0549
medium . . . . .	286	.8383 ± .0236	.4336 ± .0122	2.0276 ± .0571	.4488 ± .0126	.3564 ± .0100	2.5248 ± .0712	2.0055 ± .0565	.7915 ± .0242
dark . . . . .	97	.7635 ± .0370	.4259 ± .0206	2.2941 ± .1111	.4186 ± .0203	.3682 ± .0178	2.9290 ± .1418	1.9337 ± .0936	.7931 ± .0378
Plain, all . . . . .	412	.8216 ± .0195	.4293 ± .0100	2.0832 ± .0489	.4352 ± .0102	.3585 ± .0084	2.6013 ± .0611	1.9681 ± .0461	.7854 ± .0183
Banded, light . . . . .	27	.7083 ± .0650	.2888 ± .0264	2.2825 ± .0209	.3745 ± .0343	.2775 ± .0254	2.5713 ± .2360	2.3974 ± .2200	.7769 ± .0713
medium . . . . .	146	.8370 ± .0330	.4236 ± .0167	2.2156 ± .0875	.4156 ± .0164	.3489 ± .0138	2.5101 ± .0990	1.7276 ± .0681	.7983 ± .0314
dark . . . . .	29	.8488 ± .0752	.4050 ± .0365	1.8829 ± .1667	.4372 ± .0387	.4290 ± .0380	1.9778 ± .1751	2.1054 ± .1864	.7249 ± .0642
Banded, all . . . . .	202	.8280 ± .0273	.4073 ± .0136	2.2145 ± .0743	.4169 ± .0140	.3541 ± .0119	2.4629 ± .0826	1.8956 ± .0636	.7890 ± .0264
All [1906] . . . . .	614	.8244 ± .0158	.4231 ± .0074	2.1278 ± .0409	.4296 ± .0827	.3578 ± .0069	2.5882 ± .0498	1.9556 ± .0376	.7885 ± .0151

<sup>1</sup>The numbers are 29, 290, 100; 419: 27, 147, 29; 203: 622.

The association from the highest part of the inhabited area, collected in 1909, was markedly different in its make-up (table 243). Out of 198 individuals, 24 were sinistral, or 12 per cent (plate 34, figs. 41, 47 to 50, and 53 to 56). In both dextral and reversed groups the banded members were relatively fewer than in the collections from the middle and lower parts of the valley (plate 34, figs. 53 to 56). In coloration also the upland collection was peculiar, notably in the reduction of the characteristic strigation to such an extent that the unbanded shells presented an almost uniform appearance. Strangest of all, however, is the reddish tinge exhibited by some of the shells (plate 34, figs. 45, 46, and 51); save for the opposite nature of the coil, such

specimens resemble certain members of the *Taapuna aberrans* division of the *crassa* series. In brief, then, it appears that the primary variety *lignaria* is not uniform in its group-composition throughout the extent of the single valley that it inhabits.

Turning now to the statistical analysis of the material, we may deal first with the data relating to the 1906 series (table 244) from the lower valley. Without enumerating all of the details, it may be pointed out that the several color-classes in each of the "plain" and the "banded" sections differ *inter se*, in some cases to significant degrees. The narrower form of the shells in the case of the dark-banded division is an illustrative instance.

TABLE 245.—*Partula otaheitana lignaria*, Tipaerui Valley. Comparison of annual series.

MEAN VALUE.									
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
		<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>mm.</i>	<i>mm.</i>	<i>p. ct.</i>	<i>p. ct.</i>	
Plain, 1906, dex. . .	412	17.8767 ± .0276	10.4447 ± .0142	58.3519 ± .0692	9.4709 ± .0144	7.4660 ± .0119	78.8228 ± .0864	52.8689 ± .0652	3.3437 ± .0259
Banded, 1906, dex. .	202	17.9505 ± .0386	10.5020 ± .0193	58.4554 ± .1051	9.4356 ± .0198	7.4158 ± .0237	78.6337 ± .1169	52.4257 ± .0899	3.4581 ± .0373
Plain, 1907, dex. . .	73	18.0253 ± .0674	10.3986 ± .0323	57.4041 ± .1580	9.4014 ± .0340	7.3877 ± .0234	78.6233 ± .1960	52.0479 ± .1437	3.2432 ± .0680
Banded, 1907, dex. .	43	17.9942 ± .0837	10.4674 ± .0310	58.1047 ± .2094	9.4860 ± .0412	7.4349 ± .0286	78.4535 ± .2440	52.6163 ± .1707	3.2558 ± .0591
Plain, 1909, dex. . .	142	18.3099 ± .0478	10.4620 ± .0258	57.0845 ± .1355	9.5225 ± .0274	7.4254 ± .0237	79.0000 ± .1766	51.9648 ± .1145	3.2905 ± .0448
Banded, 1909, dex. .	26	18.4308 ± .1093	10.6000 ± .0499	57.4615 ± .3310	9.6154 ± .0493	7.5846 ± .0382	78.6923 ± .4067	52.2692 ± .2496	3.1154 ± .0923
All, 1906, dex. . . .	614	17.9010 ± .0224	10.4635 ± .0105	58.3860 ± .0579	9.4593 ± .0117	7.4495 ± .0097	78.7606 ± .0704	52.7231 ± .0532	3.3810 ± .0213
All, 1907, dex. . . .	116	18.0138 ± .0526	10.4241 ± .0235	57.2155 ± .1271	9.4328 ± .0264	7.4052 ± .0182	78.5603 ± .1530	52.2586 ± .1117	3.2479 ± .0482
All, 1909, dex. . . .	168	18.3286 ± .0438	10.4833 ± .0233	57.1429 ± .1257	9.5369 ± .0245	7.4500 ± .0211	78.1071 ± .1628	52.0119 ± .1044	3.2644 ± .0396
All, dex. . . . .	898	17.9955 ± .0180	10.4621 ± .0091	58.0757 ± .0475	9.4704 ± .0093	7.4439 ± .0077	78.6125 ± .0570	52.5301 ± .0419	3.3417 ± .0176
Plain, 1909, sin. . .	20	18.2300 ± .1065	10.6700 ± .0558	58.5000 ± .2336	9.7100 ± .0613	7.5800 ± .0576	78.1500 ± .4138	53.0500 ± .2104	3.2000 ± .1128
Banded, 1909, sin. .	4	18.4250 ± .1806	10.7500 ± .1536	58.2500 ± .4988	9.7000 ± .0954	7.6000 ± .1390	78.7500 ± 1.0496	52.5000 ± .0	3.5000 ± .3770
All, 1909, sin. . . .	24	18.2633 ± .0942	10.6833 ± .0533	58.4583 ± .2121	9.7082 ± .0536	7.5833 ± .0536	78.2500 ± .3899	52.9583 ± .1776	3.2500 ± .1070
STANDARD DEVIATION.									
Plain, 1906, dex. . .	412	0.8216 ± .0195	0.4293 ± .0100	2.0832 ± .0489	0.4352 ± .0102	0.3585 ± .0084	2.6013 ± .0611	1.9681 ± .0461	0.7854 ± .0183
Banded, 1906, dex. .	202	.8280 ± .0273	.4073 ± .0136	2.2145 ± .0743	.4169 ± .0140	.3541 ± .0119	2.4629 ± .0826	1.8956 ± .0636	.7890 ± .0264
Plain, 1907, dex. . .	73	.8539 ± .0476	.4096 ± .0228	2.0011 ± .1117	.4305 ± .0240	.2969 ± .0165	2.4825 ± .1386	1.8207 ± .1025	.8669 ± .0481
Banded, 1907, dex. .	43	.8139 ± .0592	.3017 ± .0219	2.0361 ± .1481	.4009 ± .0291	.2786 ± .0202	2.3718 ± .1725	1.6595 ± .1207	.5743 ± .0418
Plain, 1909, dex. . .	142	.8449 ± .0338	.4565 ± .0182	2.3949 ± .0958	.4847 ± .0194	.4190 ± .0167	3.1211 ± .1249	2.0233 ± .0809	.8075 ± .0317
Banded, 1909, dex. .	26	.8260 ± .0773	.3772 ± .0353	2.5035 ± .2340	.3728 ± .0348	.2891 ± .0270	3.0145 ± .2876	1.8873 ± .1765	.6976 ± .0653
All, 1906, dex. . . .	614	.8244 ± .0158	.4231 ± .0074	2.1278 ± .0409	.4296 ± .0827	.3578 ± .0069	2.5882 ± .0498	1.9556 ± .0376	.7885 ± .0151
All, 1907, dex. . . .	116	.8394 ± .0372	.3747 ± .0166	2.0291 ± .0899	.4217 ± .0187	.2906 ± .0129	2.4434 ± .1082	1.7841 ± .0790	.7724 ± .0341
All, 1909, dex. . . .	168	.8425 ± .0310	.4479 ± .0165	2.4159 ± .0889	.4704 ± .0173	.4057 ± .0149	3.1282 ± .1151	2.0056 ± .0738	.7945 ± .0280
All, dex. . . . .	898	.8460 ± .0127	.4223 ± .0064	2.2269 ± .0336	.4378 ± .0066	.3599 ± .0054	2.6739 ± .0403	1.9658 ± .0296	.7896 ± .0124
Plain, 1909, sin. . .	20	.7061 ± .0754	.3702 ± .0394	1.5491 ± .1652	.4073 ± .0433	.3815 ± .0407	2.7436 ± .2926	1.3955 ± .1488	.7483 ± .0798
Banded, 1909, sin. .	4	.5356 ± .1277	.4555 ± .1086	1.4790 ± .3527	.2828 ± .0674	.4123 ± .0983	3.1124 ± .7422	0	1.1180 ± .2665
All, 1909, sin. . . .	24	.6842 ± .0666	.3869 ± .0377	1.5405 ± .1500	.3894 ± .0379	.3891 ± .0379	2.8321 ± .2757	1.2900 ± .1256	.7772 ± .0756

A more interesting general result follows from the comparison of the several annual series (table 245). With remarkable consistence the shells become larger on the average as we ascend the valley. Still more regular are the progressive changes in proportionate measures. *In all three cases, a decrease in the figures is found.* The short series of 1909 sinistral shells agrees on the whole with the dextral group of the same locality and year.

While at first it might seem legitimate to ascribe the changes noted on passing inland to some environmental condition which became intensified in its effect in the higher parts of the valley, this would scarcely be logical in view of the contrary results discovered in the study of associations in other valleys, notably Taapuna, Papenoo, and the series inhabited by *amabilis*. Sometimes the inhabitants of the lower valley are small, as in Taapuna, but more often they are larger. It is possible, of course, to interpret the larger size of the extreme inland series—that of 1909—as the result of a selective process, for the conditions in the uplands are adverse as compared with those of the middle valley, and weak individuals also would find greater difficulty in reaching maturity. The anomalous fact would remain, however, that the series of 1906, from the lowest ground, where again adverse conditions are to be met, is made up of shells that are smaller in absolute measures. Without appealing to selection, another explanation of the facts might be found in the diverse heritage of snails living in the lowermost and uppermost areas of the whole inhabited range; the intermediate series of 1907 would then become to some extent a mixture of the two extreme stocks, and would naturally display a statistical intermediacy. Certainly the 1909 association is different from the rest in some respects, specifically in that sinistral elements occur in it; and such diversely coiled individuals do not constitute an independent stock, but they are relatives in statistical qualities, while furthermore their genetic relationship to the dextral members is proven by the data of heredity as given below. However we may interpret them, the statistics show that the snails of different areas in the inhabited range possess diverse minor qualities.

## FECUNDITY.

The statistics of fecundity (table 246) bring out certain interesting results. The series of the wet season, 1906, shows a low percentage of breeding individuals, but a fair rate of productivity on the part of such as are gravid. The series of 1907,

TABLE 246.—*Partula otaheitana lignaria*, Tīpaerui Valley. Fecundity.

Series.	Records.	No. of gravid.	Per cent gravid.	No. of eggs.	No. of young.	Total contents.	Average for gravid.	Average for all.
1906, plain, light.....	21	12	57.1	8	14	22	1.83	1.05
medium.....	215	85	39.5	37	94	131	1.54	0.61
dark.....	75	34	45.3	12	40	52	1.53	0.69
1906, banded, light.....	19	10	52.6	6	12	18	1.80	0.95
medium.....	113	52	46.0	28	56	84	1.62	0.75
dark.....	20	10	50.0	4	9	13	1.30	0.65
1906, all dex.....	463	203	43.8	95	225	320	1.58	0.69
1907, plain.....	47	28	59.6	32	20	52	1.86	1.11
banded.....	18	11	61.1	12	9	21	1.91	1.17
1907, all dex.....	65	39	60.0	44	29	73	1.87	1.12
1909, plain, dex.....	143	114	79.7	182	96	278	2.44	1.94
banded, dex.....	26	18	69.2	33	12	45	2.50	1.73
1909, plain, sin.....	15	12	80.0	17	6	23	1.92	1.53
banded, sin.....	4	3	75.0	4	5	9	3.00	2.12
1909, all dex. + sin.....	188	147	78.2	236	119	355	2.41	1.89
Total.....	716	389	54.3	375	373	748	1.92	1.04

taken during the months with less rain, comprises a larger proportion of bearing members, but their productivity is scarcely greater than before. In 1909, the snails showed a good average breeding ability, both in the proportion of gravid individuals and in the higher fecundity of these. Taking all the data into account, it would seem that in Tipaerui, at the time of the wet season, the snails were near the close of a period marked by reproductive activity, when the number of eggs was small as compared with the number of young snails about to be born. Later in the year, renewed breeding activity is manifested by more individuals, when the eggs greatly outnumber the embryonic young. With the cessation of egg-production toward the month of January, the condition of the 1906 series would again supervene.

## HEREDITY.

We come finally to the problems dealing with the genetic interrelationships (1) of the dextral and sinistral classes, (2) of the plain and banded groups treated generally, (3) of the light, medium, and dark subdivisions of the unbanded and banded classes. To these we may add (4) the more difficult question as to the possible Mendelian course of inheritance in the case of the contrasted banded and bandless characters.

TABLE 247.—*Partula otaheitana lignaria*, Tipaerui Valley. Series of 1906 and 1907.

FULL DATA OF HEREDITY.							
	Young (all dex.), plain.			Young (all dex.), banded.			Total.
	Light.	Medium.	Dark.	Light.	Medium.	Dark.	
Adults (all dex.):							
Plain, light.....	10	2	..	4	1	..	17
medium.....	42	39	2	13	8	..	104
dark.....	8	19	12	3	4	1	47
Banded, light.....	3	2	..	6	1	1	13
medium.....	8	9	4	24	17	..	62
dark.....	1	2	..	4	4	..	11
Total.....	72	73	18	54	35	2	254
	163			91			

SUMMARY. GROUND-COLOR, COMBINED PLAIN AND BANDED.				
	Young, light.	Young, medium.	Young, dark.	Total.
Adults, light.....	23	6	1	30
medium.....	87	73	6	166
dark.....	16	29	13	58
Total.....	126	108	20	254

(1) All of the snails comprising the series of 1906 and 1907 were dextral; all of the 254 embryonic young dissected from such gravid adults were also dextral (table 247). Of the mixed upland collection of 1909, the dextral adults produced only 1 out of 108 reversed young (table 248), while the sinistral adults bore 7 dextral and 8 sinistral offspring; thus the total number of reversed individuals in the

embryonic generation is less than among the adults. A secular change in the association of the higher ground may be indicated, or the figures may be too few to afford a sure basis for judgment. In either case the data have a certain positive value, especially for a future investigation of this area. The point of greatest significance is that the sinistral snails are genetically connected with the directly coiled group, which is a conclusion already drawn from the general similarity of the two groups in statistical determinations.

TABLE 248.—*Partula otaheitana lignaria*, *Tipaerui Valley*. *Series of 1909. Full data of heredity.*

	Young, dextral.		Young, sinistral.		Total.
	Plain.	Banded.	Plain.	Banded.	
Adults, dextral, plain.....	88	7	1	...	96
banded.....	3	9	..	...	12
sinistral, plain.....	7	..	3	...	10
banded.....	..	..	3	2	5
Total.....	98	16	7	2	123

(2) In investigating the heredity of the color-pattern, as unbanded or banded, some confusion might arise from the faintness of the bands in embryonic individuals, leading to their assignment to the wrong category of plain shells. Consequently, great care was taken to assure the correctness of the observations in all cases. The assembled data (table 249) give a remarkably consistent result, in that the total numbers of the two classes among the embryonic series agree closely with the figures for the corresponding classes among the parents. Each kind of the latter group contributes enough offspring to the contrasted class to bring the totals very near together.

TABLE 249.—*Partula otaheitana lignaria*, *Tipaerui Valley*. *All years combined. Heredity of plain and banded color-patterns.*

	Young, plain.	Young, banded.	Total.
Adults, plain.....	233	41	274
banded.....	35	68	103
Total.....	268	109	377

(3) When we deal with the heredity of those differences in the depth of the ground-color that differentiate the members of both plain and banded groups, other sources of error enter into the problem. A shell destined to be "dark" in the adult condition is so thin and translucent in the young stages that it might appear to belong to the "medium" group. Again, a young shell might actually be "light" and become darker-colored only later in life. As it is impossible to exclude the errors arising from these sources, we can not regard the observed data as more than approximations to the real facts. As given in table 247 for the series of 1906 and 1907, the discrepancies between the figures for the three kinds of shells among the parents and offspring indicate the effects of the errors specified above, if we assume a normal course of heredity for the character under consideration. If the contrary



supposition is made, namely, that the observations are reliable as they stand, then the figures mean that a great secular change in the direction of lighter color is taking place in the whole colony. The former assumption seems to be more warranted by all of the facts in the case.

(4) In undertaking the analysis of heredity in the case of the banded and bandless characters, the point of departure is the approximate similarity in the numerical relations of the two respective classes in the embryonic and adult series. In the next place, heredity is alternative, so far as the facts are observed. As the material to be analyzed, we have the exclusively dextral collections of 1906 and 1907, taken from closely contiguous areas; that of 1909 is to be disregarded on account of intrinsic difficulties, specifically, the small proportion of banded shells and the complication introduced by the presence of sinistral members that presumably do not freely interbreed with the dextral snails.

In the general adult population, the plain shells amount to 66.71 per cent (to be taken as two-thirds) and the banded shells to 33.28 per cent or one-third. The assumption is made that the unbanded pattern is dominant to the banded character, for which a partial justification is provided by Lang's results with *Helix*, where such is the case.

When, now, the gravid adults are classified according to their contents, they are as follows:

- (1) Plain adults: plain young only, 95; both types, 7; banded young only, 24 = 126
- (2) Banded adults: plain young only, 18; both types, 7; banded young only, 41 = 66

Assuming the banded adults to be RR, their mates would have been RR in one-third of the cases, or 22. Actually, however, there are 41, so that the difference of 19 is to be transferred to the middle class in (2). But as  $\frac{19}{41}$  of the third class really belong to the middle one, and fail to display both types of young on account of the small average numbers, there is the same correction to be made in the number of the first class. Transferring  $\frac{19}{41}$  of 18 to the middle group, the formula becomes:

- (3) Banded adults: plain young, 10; both types, 34; banded young, 22 = 66

Thus we find the relative numbers of DD and DR snails in the unbanded group.

Testing these results by comparing expectation and the actual figures in the independent series of plain parents of (1), the first step is to combine the second and third classes, because the latter comprises DR individuals mated with DR and RR. These fail to produce *both* kinds of young only because the offspring are so few. The next step is to correct the figure of the first class by subtracting  $\frac{19}{41}$ , our only basis for procedure, and assigning the same number to the middle class, when the empirical result becomes:

- (4) Plain adults: plain young, 51; both types, 75 = 126

In expectation, 29 of those adults would be DD, and whatever their mates would have been their young would be plain. Of the other 97, the expected matings and results would be as follows:

DR × DD in 10/66, or 14.7, plain young only.  
 DR × DR in 34/66, or 49.9, both types of young.  
 DR × RR in 22/66, or 32.3, both types of young.



When these figures are combined, the anticipated numbers are:

- (5) Plain adults: plain young only, 44; both types,  $82 = 126$

As compared with (4) above, there is a difference of 7, or 4.8 per cent of the whole number. The agreement is so close as to support the view that a Mendelian order of inheritance is followed in the history of the banded and bandless characters.

When the factor for the plain pattern is assumed to be the recessive member of a Mendelian pair, the three gametic classes come out in the unsatisfactory proportions of 1 : 1 : 4, which would not give a relatively stable colonial condition; this offsets the fact that the difference between expectation and observation in the test of the numerical relations amounts to only 3.8 per cent.

#### SUMMARY AND CONCLUSION.

The variety of *Partula otaheitana* called *lignaria*, which inhabits Tipaerui Valley, is well separated from the forms occupying the neighboring valleys on either side, namely, Fautaua and Taapuna, in correspondence with its topographical discontinuity. In general terms, it differs qualitatively from the Fautaua association, (1) in the great preponderance of dextral members, (2) in the characteristic strigations displayed by almost all of the members, (3) by an abundance of banded components, and (4) by the absence of the red color-factor except in a small number of its upland population. It is distinguished from the Taapuna Valley association to the southwest, (1) by its dominant dextral coil, (2) by its strigated pattern, (3) by the large number of striped members, and (4) by the general absence of the reddish or yellowish ground-color.

Quantitatively, the *lignaria* variety differs from the colonies on either side as indicated below (table 250), the facts being self-evident from the figures. A notable point is the astounding difference in all respects between the apertures of *lignaria* and *crassa aberrans*; in the matter of proportions, the difference is more than 30 times the probable error.

TABLE 250.—*Partula otaheitana lignaria dextral in comparison with Partula otaheitana otaheitana dextral and Partula otaheitana crassa aberrans sinistral.*

Character.	As compared with <i>P. o. otaheitana</i> , Fautaua.	As compared with <i>P. o. crassa aberrans</i> , Taapuna.
Shell length, mm. ....	-1.3229 ± .0353	[-0.0668 ± .0453]
width, mm. ....	-.5115 ± .0194	[-.0123 ± .0219]
proportions, per cent. ....	+1.3310 ± .0884	[+.1693 ± .1101]
Aperture length, mm. ....	-.4149 ± .0188	-.1940 ± .0227
width, mm. ....	-.2228 ± .0151	+.2918 ± .0189
proportions, per cent. ....	+1.1149 ± .1097	+4.7335 ± .1406
Length aperture ÷ length shell, proportions, per cent. . .	+1.4125 ± .0768	-.8831 ± .0926
Tooth. ....	+.5817 ± .0338	+.9183 ± .0458

## GENERAL SUMMARY.

It is now desirable to treat the present species in a somewhat comprehensive way, in order to bring out certain details in clearer relief and to set forth the wider significance of the detailed observations that have been described, as the author conceives their meaning. In concluding the sections concerned with the several primary varieties, summaries have been presented that render it unnecessary to recall the minor details or the subordinate matters of interpretation, of which the latter, save where they relate to classified concrete data, are always to be considered as secondary in importance to the observations themselves. It must not be forgotten that the main purpose kept in mind throughout the study of this and of the other species has been to give a precise, detailed description of the primary and subordinate varieties and of their exact situations; the value of the task, so far as it has been accomplished, lies in the service it may be to future investigators who, after the lapse of years, may carry on similar studies in order to determine the nature and rapidity of the evolutionary changes that may take place in the interim. Nevertheless, the summarized observations reveal certain significant relations, and it is with such intrinsic meanings that we are now concerned.

I. *Partula otaheitana* is ubiquitous in Tahiti, in one or another of its forms; it is usually abundant wherever the ecological conditions are such as to permit the existence of any Partulæ, and it is very variable. Therefore it offers an interesting contrast to all of the other species of its island, no two of which, indeed, are alike in the extent of the territory occupied or in the degree of their intrinsic differentiation. *Partula hyalina* is widespread but not abundant, and it exhibits very little diversification among its colonies, now as heretofore. *Partula clara* has recently extended its range greatly, it has increased in numbers, and it has advanced in complexity, but as yet it has come to equal only a primary variety of *otaheitana*, such as *affinis* or *sinistrorsa*. *Partula nodosa* has paralleled *clara* in some of these respects, but falls short of the latter. Finally, *Partula filosa* is rigidly restricted to a single valley, where it thrives in numbers and varies considerably. Nothing could be more favorable for studies of the present kind than these conditions of the species of Tahiti, their diversity as regards matters of detail, such as the above, and the uniformity of the underlying principles of distribution and evolution.

II. The closest relatives of *Partula otaheitana*, taken as a whole, do not occur in Tahiti; they are the many dextral species of Raiatea, and probably also the sinistral *Partula mooreana* of the neighboring island. These species occupy well-separated land-masses and well illustrate Jordan's principle that related *species* are to be found in non-contiguous areas. Such a condition, however, is to be regarded as a derived one, for at the outset the strains that are destined to diverge in subsequent times are necessarily close associates in a geographical sense in correspondence with their genetic intimacy—which is amply proven by the descriptive account of the varieties in the present monograph.

The occurrence of related forms in Tahiti, Raiatea, and Moorea means that in former remote times these islands were connected by land; that the common

ancestral stock ranged over the whole land-mass, and that its local products differentiated into the distinct species after the process of subsidence had isolated the mountains now forming the separate islands. The alternative view is that human carriers have introduced *otaheitana* into Moorea and Raiatea, there to assume new characteristics, or that some one of this group of species is immediately ancestral to the others. But this seems less tenable than the one adopted, especially in view of the collateral evidence that *Partula attenuata* exists in Tahiti and Raiatea, in the upper part of the valleys, and upon the higher branches of the trees; the human factor is certainly eliminated in such a case, and there is no more reason to postulate its interposition in the case of *otaheitana* and its relatives. It is true that other products of the ancestral stock might have persisted for a time in Tahiti in company with *otaheitana*, or in Moorea, but if they did they have long since disappeared; even so, the essential principle involved remains the same without qualification.

III. The original pro-*otaheitana* stock of Tahiti, after the isolation of the island became resolved into the eight primary varieties herein distinguished, viz, *otaheitana* sensu var., *amabilis*, *rubescens*, *affinis*, the *sinistrorsa-sinistralis-crassa* series, and *lignaria*. While questions arise as to the location of the areas where each took its present form, these may be passed over for the time in favor of the problem concerned with the reality of the interrelationships among the several divisions of the species. These have come to differ to greater or lesser degrees, it is true, and are so situated geographically that they can not generally interbreed, yet collectively they are well separated from the other forms of Tahiti and are morphologically related to one another; the facts given in detail in the circumstantial analysis provide the requisite evidences.

Among the more interesting and significant points to be recalled in this connection are the sporadic manifestations in one variety of characters that are distinguishing marks of another division. For example, the sinistral coil that is exclusive in *rubescens* and dominant in the *sinistrorsa-sinistralis-crassa* series occurs by mutation in *affinis* and *lignaria*, which are usually dextral; conversely, the dextral character of the latter varieties is displayed by a few or by many individuals in colonies belonging to the triple reversed series of the south and west; the red and clearer yellow colors of *rubescens* appear infrequently in *affinis*, but they constitute the distinctive colonial qualities of *crassa occidentalis* of Aoua and Papehuc Valleys, whose typical relatives are brown; the bicolored pattern is produced in one colony of *rubescens* and in two widely separated associations of *affinis*; giant adolescents far above the average appear in *affinis* and in *sinistrorsa*, which attain the great size of best-developed *rubescens* shells; dwarfs are found in certain *rubescens* and other colonies among snails that are usually large.

The relationships in question being recognized, the next point is that the present *otaheitana otaheitana* association of Fautaua Valley best represents the original ancestral stock of the species, for only in that colony do we find all of the characteristics that are displayed in one or another combination by the distinguishable varieties. While the condition of *otaheitana otaheitana* might conceivably be brought about by a synthesis of characters contributed by two or more well-

separated varieties, such as *affinis* and *rubescens*, it is more reasonable to view the antithetic or sharply contrasted conditions of the latter as derived from a group of snails with a composite make-up like that of the Fautaua colony. Purely sinistral *rubescens* and predominately dextral *affinis* do not interbreed in the areas that they now share in common, while furthermore they could scarcely merge their diverse modes of coil as readily as each could arise from a mixed colony, where sinistrality and dextrality are almost matters of indifference, where adults of one kind so frequently produce offspring of the other, as in Fautaua at the present time. The variations in color and size exhibited by the snails of Fautaua are most reasonably interpreted as persistent counterparts of the original varied complex of characters possessed by the forerunners of the now divergent and well-demarcated varieties; they repeat the points of departure of the lines of differentiation which culminate, *inter alia*, in the small, brown dextral shells of *affinis* and the large sinistral shells of *rubescens* with red and yellow colors.

IV. Each primary variety assumed its more or less divergent distinctive qualities in a somewhat restricted locality, and not in all parts of the island. In the author's view, the colony of Fautaua Valley is to be regarded as relatively unchanged and as a persistent representative *in situ* of the ancestral complex. The *amabilis* associations, differing among themselves, have collectively departed to appreciable degrees from their forerunners without question in the same areas where they are now found; the intervening barriers between contiguous habitable areas are such as to prevent intercommunication almost if not quite completely. *P. rubescens* and *affinis* present a very interesting problem, because their ranges are almost coincident throughout and because they are mutually antithetic in their distinctive qualities, about which enough has already been said; that both varieties originated in the eastern sector is indicated by the topographical and ecological conditions of their territories, and it is relatively unimportant whether both arose along diverging lines in the same sector or different subsidiary regions of the east. The sinistral series of the south and west must have developed its characteristics in the south or southwest, thence to spread and to differentiate into the three components of to-day. Finally *lignaria* is undoubtedly a local product of the pro-*otaheitana* stock that became cut off in the valley of Tipaerui.

From what may be learned about the most recent episodes in this whole history, progress in the differentiation of a particular colony is made by the dropping out of a character, just as *rubescens* has lost the dextral form of coil attributed to its ancestor and as it has gained the clearer yellow and red colors by the elimination of the brown, and also by the process of mutation in the narrower sense. Sporadic giants among small-shelled snails and anomalous banded color-forms are illustrative of the latter.

In all of this history, due recognition must be given to the flow and ebb of tides of migration, necessarily of slow movement, such as the wave of *nodosa* that has reached beyond Punaruu Valley as far as Orofere. Subsequent processes of differentiation may or not take place; *rubescens* is certainly invariable in color-character throughout its wide range, while *crassa* has greatly diversified in its compact sector

TABLE 252. *Partula otaheitana*. Summary graphic representation of the ranges and mean values of the standard characters of the eight primary varieties. (Sinistral, full lines; dextral, interrupted lines.)

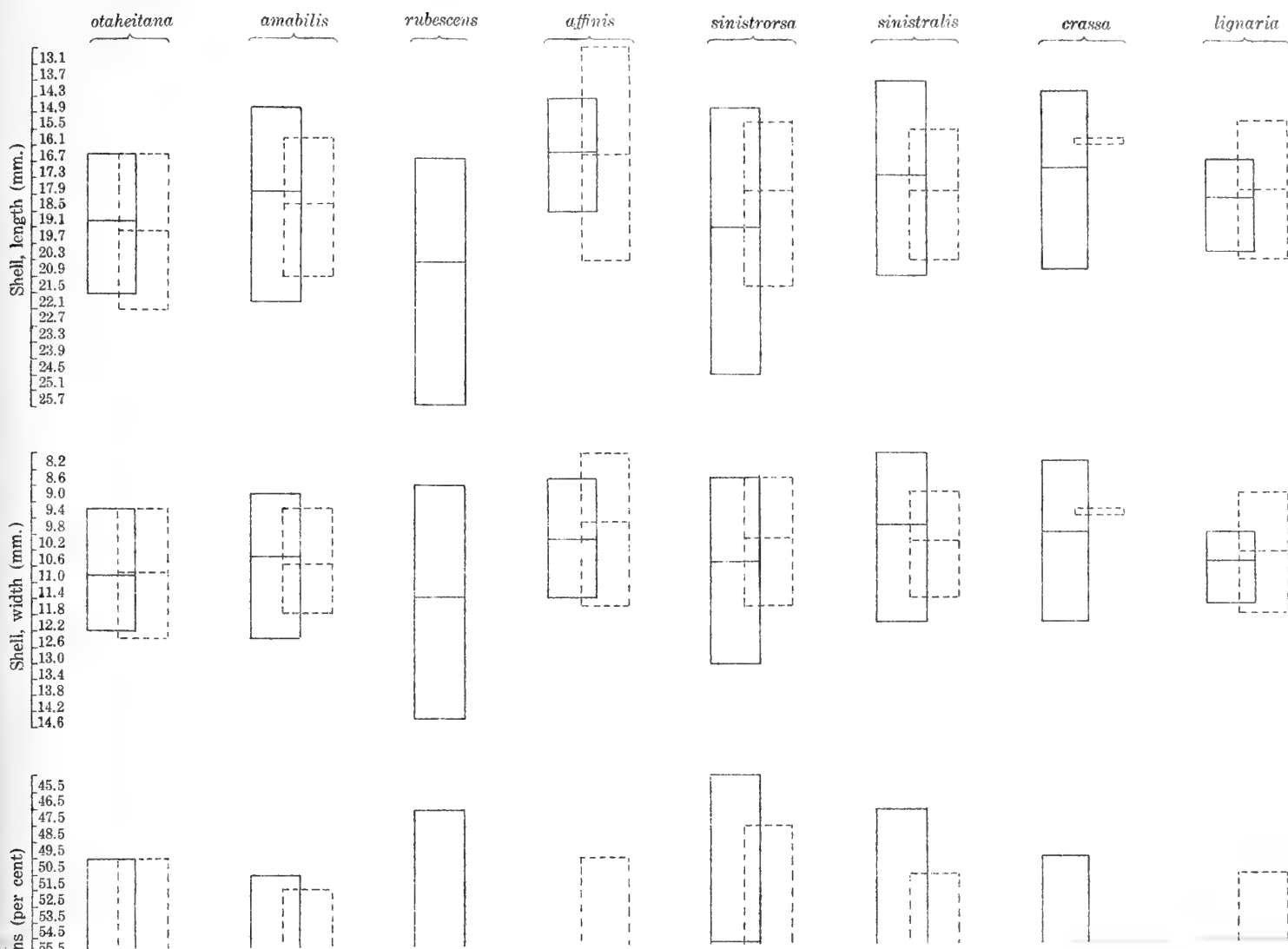
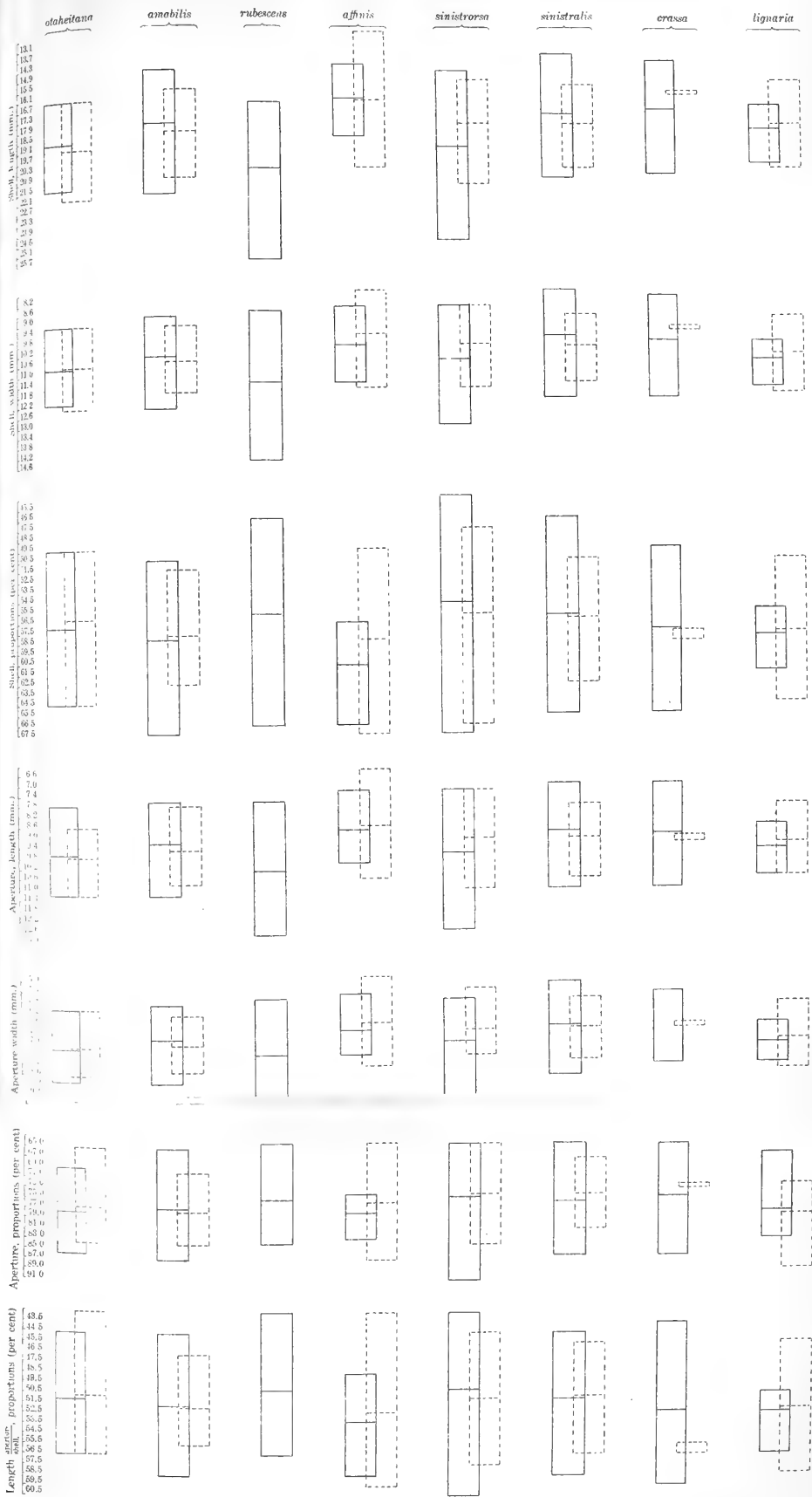




TABLE 252. *Partula otaheitana*. Summary graphic representation of the ranges and mean values of the standard characters of the eight primary varieties. (Sinistral, full lines; dextral, interrupted lines.)







of occurrence. The newer type, when such has arisen, may increase in numbers so as to overwhelm the original kind, as in the case of *crassa occidentalis*, or the mutations may be only abortive steps toward the production of a new complex of qualities.

V. From the present study, the congenital factors of variation seem to be paramount in comparison with the "environmental" influences affecting the snails. Doubtless there are few who would hold external circumstances accountable for the existence of different combinations of *species* in different localities, such as *hyalina* and *otaheitana* in Fautaua Valley, and *hyalina*, *clara*, *nodosa*, and *otaheitana* in Punaruu Valley. It is equally difficult to discern reasons for regarding diverse combinations of *varieties* as the products of one and the same environment, such as *rubescens* and *affinis* in Papenoo, *rubescens*, *affinis*, and *sinistrorsa* in Apirimaue, or *sinistrorsa* and *affinis* in Vavii, when a few miles away in Aiurua the associates are *rubescens* and *affinis*.

As to *subvarieties*, the sporadic occurrence of reversed or peculiarly banded *affinis* in widely separated localities could scarcely signify the operation of identical external factors in such places and not in the intervening territory; dextral sports produced in greater or less abundance in certain colonies of *sinistrorsa* and *sinistralis* surely can not arise except through the operation of congenital factors that are independent of the environment.

But it is not necessary to review the whole case at length, for in many of the foregoing pages the significance of the facts as observed has been pointed out. Brought down to their most succinct expression, the general conclusions are:

(1) The negative statement that no differences in the environmental factors affecting the Partulæ can be discovered which would account for the production of diverse but intimately related forms in two contiguous valleys, such as typical *crassa* and *crassa occidentalis* in Orofere and Aoua Valleys, respectively.

(2) The argument from the positive observations that in species *X* the colonies of two valleys are alike, while in the associated species *Y* the snails of the same areas are unlike. It is merely an appeal to ignorance to contend that, because two distinguishable types occur in neighboring localities, there must be environmental factors for the observed differences; but even this contention breaks down when individuals of a mutant group, like dextral *sinistrorsa*, appear in a valley *along with their unchanged relatives*. In a word, the rôle of the environment is to set the limits to the habitable areas or to bring about the elimination of individuals *whose qualities are otherwise determined, that is, by congenital factors*.

VI. It remains only to bring together general statistical summaries relating to the standard characters of the *otaheitana* shells. The figures for the several varieties are given in table 251, while table 252 shows the ranges and the means of the characters in both the sinistral and dextral divisions of each variety. Too much significance must not be attached to the data in certain cases, such as that of sinistral *affinis*, for the constituents are few and are widely scattered; similarly, the dextral groups of both *sinistrorsa* and *sinistralis* are locally represented, and are to be

compared collectively, if at all, with their combined sinistral associates. Yet with all qualifications, duly set forth in the special summaries, the figures define the different divisions of *Partula otaheitana*—the most complex species belonging to the genus.

TABLE 251.—*Partula otaheitana*. General statistical description of the primary varieties. Sinistral individuals=12,684; dextral individuals=7,510; total number=20,194. (The numbers for the tooth are greater.) Mean value.

Variety.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.	Tooth, index.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.		
		mm.	mm.	p. ct.	mm.	mm.	p. ct.	p. ct.	
<i>otaheitana</i> , sin. . .	506	19.1003±.0268	10.9888±.0142	57.4373±.0719	9.8321±.0142	7.7239±.0115	78.4744±.0818	51.4076±.0590	2.7138±.0267
dex. . .	421	19.3184±.0304	10.9736±.0172	56.7447±.0745	9.8853±.0163	7.6667±.0130	77.4976±.0937	51.1176±.0644	2.7600±.0289
<i>amabilis</i> , sin. . .	1,947	18.0018±.0151	10.5839±.0076	58.7547±.0368	9.3931±.0078	7.3152±.0065	77.8426±.0435	52.0881±.0293	2.8292±.0122
dex. . .	167	18.4955±.0474	10.7851±.0260	58.2186±.1119	9.6521±.0283	7.5407±.0215	78.0509±.1491	52.1347±.0934	3.0000±.0375
<i>rubescens</i> , sin. . .	1,436	20.6411±.0266	11.5942±.0154	56.1709±.0478	10.4608±.0134	7.9475±.0100	76.0105±.0539	50.6772±.0337	1.5578±.0171
dex. . .	0								
<i>affinis</i> , sin. . . . .	26	16.5962±.1544	10.1462±.0877	61.1154±.3027	8.9385±.0893	7.0077±.0735	78.4615±.2528	53.7692±.2948	2.1539±.1142
dex. . . . .	5,114	16.6187±.0092	9.7068±.0049	58.7047±.0209	8.8076±.0052	6.7488±.0042	76.5190±.0261	52.8743±.0175	2.3125±.0071
<i>sinistrorsa</i> , sin. . .	3,422	19.3845±.0161	10.7015±.0072	55.1979±.0284	9.8033±.0079	7.4162±.0055	75.6373±.0323	50.5368±.0223	1.0964±.0041
dex. . .	674	17.9926±.0221	10.1199±.0112	56.1810±.0612	9.2736±.0123	6.9591±.0093	74.9703±.0704	51.4703±.0517	2.1694±.0300
<i>sinistralis</i> , sin. . .	2,603	17.4493±.0139	9.8536±.0073	56.4063±.0312	8.9975±.0074	6.8536±.0057	76.1162±.0355	51.4573±.0237	2.5943±.0122
dex. . .	235	17.9926±.0358	10.2081±.0178	56.6702±.0938	9.2336±.0192	6.9196±.0152	74.8234±.1057	51.2362±.0817	1.6568±.0362
<i>crassa</i> , sin. . . . .	2,720	17.2787±.0117	10.0069±.0066	57.8423±.0324	9.1292±.0067	6.8899±.0051	75.3860±.0379	52.7566±.0260	2.5122±.0120
dex. . . . .	1	16.25	9.5	58.5	9.3	6.9	73.5	56.5	3
<i>lignaria</i> , sin. . . .	24	18.2633±.0942	10.6833±.0533	58.4583±.2121	9.7082±.0536	7.5833±.0536	78.2500±.3899	52.9583±.1776	3.2500±.1070
dex. . . . .	898	17.9955±.0180	10.4621±.0091	58.0757±.0475	9.4704±.0093	7.4439±.0077	78.6125±.0570	52.5301±.0419	3.3417±.0176

## CHAPTER VIII.

### PARTULA PRODUCTA Pease.

Sharply contrasted with the preceding species, *Partula producta* occurs in a closely restricted habitat, in smaller relative numbers, and it is terrestrial; hence it is the complete antithesis of *Partula otaheitana*, which is abundant, widespread, and arboreal. In my own experience, *producta* was found in a single valley only, namely, Faarahi in the district of Mataiea, near the center of the southern sector of Tahiti nui. Garrett says (p. 66):

"This species only occurred to my notice in one valley, on the southwest coast of Tahiti, where it is abundant, lurking beneath decaying leaves and under heaps of loose tones."

The map made by Garrett and published in Hartman's paper (*cf.* text-fig. 2) seems to indicate a locality in Mataiea; yet when Garrett describes the various subspecies of *otaheitana* (p. 49) he interjects a paragraph relating to this species, as follows:

"It is worthy of remark that in that part of the district of Papieri [*sic*] occupied by *sinistrorsa*, is also the headquarters of the terrestrial *P. producta*, a dextral species which is always edentate, and exhibits the fasciation of the former."

There is no political division named Papieri. Papeari is the district just to the east of Mataiea, while Papara adjoins it on the west, and is nearer the valley in which I found *P. producta*. Obviously Garrett meant either Papeari or Papara; that it was the former, we may be sure from the fact that *sinistrorsa* occurs in Papeari, while the relatives properly distinguished by Garrett as *sinistralis* inhabit Papara. There still remains the possibility that Garrett did find *producta* in a valley to the east of Faarahi, actually located in Papeari, in which I failed to rediscover the species; the probability of this supposition is not great, because every effort was made in my own collecting along the southern coast to find *producta*, which is somewhat elusive, even in Faarahi, on account of its terrestrial habit. Dextral banded snails were found, as we have seen, but they proved to be more or less abundant relations of the reversed *sinistrorsa*, etc. The true *producta* can not be confused with anything else, when it is examined carefully. In brief, the evidence tends to prove that the single valley inhabited by *producta* in Garrett's time was Faarahi, the same that in my experience is the present area of occurrence.

Pease described *P. producta* in 1864, almost undoubtedly on the basis of specimens collected and forwarded by Garrett. The formal description is as follows:

"*P. t. elongato-ovata*, dextrorsa, solida, compresse umbilicata, tenuiter et irregulariter longitudinaliter striata; anfr. v., plano-convexis, sutura impressa; apertura oblongo-ovata, labro anguste rotundato; fusca vel flavicanter fusca, nigro-fusco trifasciata.

"Long. 22, diam. 12 mill.

"The above species is wholly terrestrial in its habits; the lip on mature or old specimens is united over the body-whorl by a callosity."

Hartman, writing in 1881, speaks of *producta* as a terrestrial species, that "may be confused with dextral banded *P. otaheitana* without a pillar tooth." The details of the coloration are such as to make identification always certain, while the form and proportions are so distinctive as to be sure criteria for both the unbanded and banded shells. The species is readily distinguishable from the dextral mutants of *P. otaheitana sinistrorsa*, which occur in this valley in small numbers, as we have seen.

Garrett's descriptive account (pp. 66, 67, *loc. cit.*) is as follows:

"The type is yellowish fulvous, and invariably marked by three narrow, revolving, reddish brown bands in the body-whorl, and two on the spire. The rather narrow, dull whitish peristome is moderately reflexed, rounded, and the margins united by a layer of callus on the parietal wall, which latter is edentate. It is always dextral, and the rather long spire equals half, or a trifle more than half, the length of the shell.

"Var. *a*. Body deep chestnut-brown, with or without a pale sutural band, pale base and bilineated spire.

"Var. *b*. Uniform pale fulvous or tawny, with a darker apex."

Pilsbry gives a full description in his classic work, which is as follows:

"The shell is dextral, long-ovate, deeply rimate, rather solid, moderately glossy; yellow or brownish-yellow with three dark chestnut bands, a pale sutural band above the upper one, the middle band widest, the lower one defining a light umbilical patch; whorls of the spire showing two dark bands on a light or flesh-colored ground, apex dark. The surface shows *no spiral lines*, or only faint traces of them. Whorls  $5\frac{1}{2}$ , moderately convex, the last well rounded peripherally and beneath. The aperture is nearly vertical, dark within; peristome narrowly expanded and reflexed, moderately thickened within, white or flesh-tinted. The parietal wall is typically toothless, but sometimes it bears a tubercular white tooth.

"Length 20, diam. 10.7, aperture 10 mm.

"Length 19, diam. 10.2, aperture 10 mm.

"Length 21, diam. 11.2, aperture 10.8 mm.

"Length 18.8, diam. 10, aperture 9.8 mm."

The material in hand is scanty. Only 29 living adults and 3 adolescents were collected, as well as 14 "dead" shells of adult growth that may be used in the statistical analysis. In examining the collections in the museums of Honolulu, and of various places in America and Europe, some two score shells were studied, all of which agree with the material obtained personally.

The color-form regarded as typical is that which displays three distinct revolving bands upon the body-whorl (plate 34, figs. 57 to 59). The bands themselves are regularly spaced; the median element corresponds in position with the middle stripe in *affinis dubia* and *zonata*, and others, but the lateral markings are nearer to the morphological sagittal plane than in the varieties of *otaheitana*. As a consequence, the sutural zone of the body-whorl and of the apical coils, as well as the extreme basal or umbilical region of the last whorl, exhibit the ground-color. Upon the spire, the "basal" band is covered, and therefore only two elements are displayed. It is noteworthy that in *sinistrorsa cestata* the sutural band is in contact with the whorl next above, which affords a sharp contrast with the *producta* condition.

The even dark-brown color of some specimens (plate 34, fig. 63) is the product of an ultimate suffusion of bands that are elsewhere more or less vague but recognizable (plate 34, figs. 61 and 62). Finally, very light specimens occur (plate 34, fig. 64) which seem to be derivatives of faintly banded types like that of figure 60, plate 34, in which the stripes have become evanescent; in practically every case, in my own and in other collections, some trace of the bands is discoverable, even though it may be very faint. The point at issue is that the three color-types of *sinistrorsa*, namely apex, cestata, and phæa solida are not repeated exactly in this species; the three forms actually found are reducible to one, which does not agree with cestata in the details of the revolving bands, however much it may resemble the latter on casual inspection and acquaintance.

Defined statistically (table 252) the species proves to be somewhat similar to its *sinistrorsa* associates, but it is clearly distinct, especially in the characters of the aperture. Only one shell exhibited a weakly developed trace of a pillar tooth.

TABLE 252.—*Partula producta*, Faarahi Valley. Statistical description.

MEAN VALUE.								
Series.	No.	Shell.			Aperture.			Length aperture ÷ length shell, proportions.
		Length.	Width.	Proportions.	Length.	Width.	Proportions.	
		mm.	mm.	p. ct.	mm.	mm.	p. ct.	p. ct.
Live...	29	18.9224 ± .1180	10.2172 ± .0403	53.9482 ± .2474	9.5758 ± .0571	7.0449 ± .0308	73.3965 ± .2948	50.4311 ± .1971
Dead..	14	19.2142 ± .1503	10.1427 ± .0736	52.9286 ± .4899	9.6143 ± .0814	6.9000 ± .0721	71.9286 ± .6045	49.9286 ± .2785
All..	43	19.0174 ± .0943	10.1930 ± .0364	53.6163 ± .2360	9.5883 ± .0468	6.9976 ± .0321	72.9186 ± .2886	50.2675 ± .1628
STANDARD DEVIATION.								
Live...	29	0.9428 ± .0834	0.3217 ± .0285	1.9753 ± .1749	0.4561 ± .0404	0.2457 ± .0218	2.3539 ± .2084	1.5741 ± .1393
Dead..	14	.8338 ± .1063	.4083 ± .0520	2.7180 ± .3464	.4517 ± .0575	.4000 ± .0510	3.3533 ± .4274	1.5452 ± .1969
All..	43	.9172 ± .0667	.3539 ± .0257	2.2947 ± .1669	.4551 ± .0331	.3122 ± .0227	2.8056 ± .2041	1.5824 ± .1151

The data on fecundity are: records, 29; gravid, 25; per cent gravid, 86.2; eggs, 26; young, 17; total contents, 43; average for gravid, 1.72; average for all, 1.48.

Of the young, 16 were dextral and banded; only 1 was devoid of recognizable bands, but its whorls were lighter just below the suture, so that its condition supports the view expressed above as to the relationship between the light plain shells, and the banded individuals; this embryo, like the rest, was dextral.

As *Partula producta* was found in one situation only, it does not afford an opportunity for the study of distribution. Its intrinsic characters and internal variation are of some interest, especially in connection with a wider analysis of the whole genus, when terrestrial species of other islands, notably Raiatea, are investigated. For the present, it stands alone on account of its many points of contrast with the other forms of Tahiti.



## CHAPTER IX.

### RÉSUMÉ.

---

#### INTRODUCTION.

The investigations described in part in the present volume are concerned with the natural history of land-snails belonging to the genus *Partula* of Férussac. In the course of four journeys of exploration in Polynesia, the author has collected an abundance of material which makes it possible to study specific variation, distribution, and evolution by using the precise quantitative methods of biometry, always with a view to the assignment of definite relative values to the congenital and external factors of differentiation. The results as they are given for the forms of Tahiti and as they will be presented in subsequent volumes constitute an analysis of the existing situations and conditions of the several species, interpreted to some extent in terms of the earlier descriptions given by Garrett and Mayer, while in addition they provide a sure basis of comparison for similar comprehensive investigations that may be prosecuted after the lapse of decades.

#### CHAPTER I.

The organisms under consideration live on certain of the oceanic islands of the south and west Pacific Ocean with headquarters in the Society Islands, of which Tahiti is the largest and best-known member. Each group and each inhabited island bears characteristic species not found elsewhere, with only rare and peculiar exceptions; hence the geographical conditions are ideal for the study of the correlation between the degrees of resemblance exhibited by the species and the degrees of proximity or isolation of their territories. Almost without exception the snails occur on the larger "high" islands of ancient volcanic construction, where they live in the moist areas of the valleys, in more or less isolated colonies. An analysis of the geological, climatological, and barometric conditions rules out such elements as factors of differentiation, although they set the limits to the areas within which the organisms may maintain themselves. Although the food of the animals consists of decayed vegetable matter, there is no discernible relation between a given species and a definite botanical associate.

#### CHAPTER II.

The present volume deals with the species of Tahiti only. In the course of the writer's field work, more than 25,000 adult specimens were obtained, together with over 7,000 adolescent individuals; as the snails are viviparous in habit, many thousands of the offspring which exhibit their taxonomic peculiarities have been dissected out of the brood pouches of their parents.

Eight species in all are recorded from Tahiti, namely *P. hyalina* Broderip, *P. clara* Pease, *P. filosa* Pfeiffer, *P. nodosa* Pfeiffer, *P. otaheitana* Bruguière, *P. producta* Pease, *P. attenuata* Pease, and *P. stolidus* Garrett. The last two have not been investigated like the others; *P. attenuata* is a rare inhabitant of the highest

branches of the trees of upper regions, and was collected in very sparse numbers, while *P. stolidus*, called *compressa* by Pilsbry, has been stated to occur in a single valley, where repeated search for it was futile.

The six species under investigation differ greatly in their degrees of distinction, in their intrinsic diversification, and in the relative extent of their territories of occupation; accordingly each one presents features of peculiar and special interest in addition to those that they share in common. At the outset, a detailed description is given of the geographical and topographical features of Tahiti, in order that the exact situations of the several colonies belonging to these species may be clearly defined and understood. The tables give the numbers of each species that were found in one, few, or many of the sixty-two valleys where any snails whatsoever were obtained.

In studying the animals for the purpose of qualitative and quantitative comparison, the standard characters of the shells were employed, although the soft bodies have been preserved for any further investigation that may seem desirable. The well-established statistical methods that give the type measure and its variation in each of the characters defined quantitatively prove to be indispensable for the definition of precise degrees of similarity and difference in the case of comparable species, subspecies, and component groups of lesser order.

#### CHAPTER III.

The first species described, *P. hyalina* Broderip, is unique in the fact that it occurs on islands belonging to the Society, Cook, and Austral groups, but not in all of the members of any one group, even in the case of the last-named, which is regarded as its headquarters. The shell is always clear white, and has thus reached the limit of specialization in the loss of color. The species is distributed widely in Tahiti where it has been regarded as invariable, but biometric methods reveal differences where none would appear without the employment of such means.

Variations in the numerical abundance of this species in the fifty-one valleys of its collection are discussed at some length, with the conclusion that such variations are to be regarded as the products of constitutional differences and not of external circumstances. It is true that the drier quadrants of Tahiti, and the larger, less humid valleys are most favorable for this type, but the members of the several *hyalina* colonies vary constitutionally, so as to possess diverse degrees of ability or inability to meet the particular conditions of their respective localities. The data of fecundity show the highest rate of any species. Using these for an analysis of post-embryonic elimination, it appears that about two-fifths of a new-born generation will survive to reproductive maturity.

The writer's studies on this species have been extended to the Cook Islands, where a few specimens were secured from Mangaia and Moki. The shells exhibit certain statistical peculiarities when they are compared with those from Tahiti.

Passing to the general discussion of the unique distribution of *P. hyalina*, the fundamental facts are that it occurs in such widely separated islands as Tahiti of the Society Group, Moki and Mangaia of the Cook or Hervey Group, as well as in



Rurutu and Tubuai of the Austral Group—in all of which it displays the true diagnostic characters of the species with only quantitative differences. Next in significance is the absence of *hyalina* from the other islands of the three groups specified. After weighing the evidences for the two alternative views (1) that human agencies have been responsible for the introduction of the species from one of the three groups to the other two, and (2) that *hyalina* is a very ancient species which had attained its present characteristics before the old and continuous mountain ranges had been isolated by subsidence so as to become separate islands and island groups, judgment is given in favor of the second.

#### CHAPTER IV.

*Partula clara* Pease is a well-separated species and is typical in its restriction to a single island. Its colonies now exist in the valleys of about four-fifths of Tahiti, and they display exceedingly significant variations in size, shape, coloration, and texture. More than 1,000 adults and adolescents were secured. For the sake of a comparison with *P. hyalina*, the statistical description begins with the general treatment of the whole series; subsequently the populations of the major ecological regions are compared, and finally the several valley colonies are biometrically defined in geographical order.

When the statements of Garrett and Mayer are taken into full account, the results of the present investigation are significant of many evolutionary changes. The species was rare in Garrett's time in the islands (1861–1888) and was found “in the upper portions of the valleys in the southwest part of Tahiti.” Mayer (1899) found that *clara* constituted 10 per cent of the population of a certain valley (Vaihiria), while in my later experience it formed 23 per cent. In fine, the “rare” species of Garrett now amounts to 3.4 per cent of the island *Partulæ*, to 4.5 per cent of the population of the inhabited sector, and to 5.1 per cent of the total number of snails in the valleys of its collection.

Again, the species was earlier restricted to a small southern sector, as Garrett's evidence attests, while now it ranges throughout four-fifths of the whole island. Furthermore, in addition to its spontaneous dispersal, it has become differentiated into distinguishable subspecies, viz. *parva*, *incrassa*, *minor*, *angusta*, *prima*, *marmorata*, each of which has its proper territory, though this may be an old or a new-won region of the island. Mutation has taken place in some, but not in all, of the localities into which migration has extended, and it has occurred also in parts of the former territory of occupation. The evidence in summary indicates that this species is one which has recently revived and developed after a long period of racial decline.

#### CHAPTER V.

In sharp contrast with the other arboreal species of Tahiti, *Partula filosa* Pfeiffer is restricted to a single valley (Pirai) situated in the drier northwestern sector of the island; yet in spite of its rigid confinement to one valley, the species is far from invariable, no less than five color classes being distinguishable, together with statistical differences between the sub-colonies of the upper and lower portions of

the continuous area of habitation. Probably the latter points of contrast indicate the results of a selective process by which the less vigorous individuals are eliminated in unfavorable parts of the valley. This species is the sole relic of a series of forms having a wider range in Tahiti in earlier times, but whose representatives have disappeared elsewhere on account of their constitutional inability to meet the environmental conditions of existence.

#### CHAPTER VI.

The beautiful species described by Pfeiffer as *P. nodosa* and by Pease as *P. trilineata* inhabits a series of seven consecutive valleys in the western quadrant of Tahiti nui, where more than 2,000 full-grown and adolescent individuals were collected. The area of occupation is more compact than in the case of *P. clara*, though it is not so contracted as in the case of *P. filosa*.

The analysis of the characteristics of the shells, as these are defined both qualitatively and quantitatively, leads to certain significant conclusions regarding the past history of the species and its differentiation. The first general point is that *P. nodosa* has expanded its territory of occupation during recent decades. In Garrett's experience it was limited to a narrowly circumscribed territory on one side of the stream in the great valley of Punaruu, while now it exists also in one valley to the northward and in five more to the southward; the tide of immigration seems to have reached the most distant of the new areas between the years of the author's third and fourth expedition. Like *P. clara*, therefore, *P. nodosa* has recently entered upon an epoch of renewed vigor, as manifested by its increase in numbers and in the area of its extent; previously it had become restricted to a small and confined territory, as in the case of *P. filosa*, and was in danger of extinction.

The species is far from uniform throughout its range, as regards the secondary characters of the shells. Four varieties are herein established on the basis of geographical location and intrinsic differentiation; they are *composita* Cr. in Taapuna and Punaruu Valleys, *læva* Pilsbry of Maruapoo Valley (*sinistralis* of Mayer), *exigua* Cr. of Atehi Valley, and *intermedia* Cr. of Papehue, Aoua, and Orofere Valleys. The first is predominantly dextral, the second is almost entirely sinistral, while in the fourth, reversed shells are produced only sporadically. Furthermore, four color-classes are distinguished, some of which have been given varietal names by earlier authors; they are *pallidior* Pilsbry, *trilineata* Pease, *nodosa* Pfeiffer, and *concrescens* Cr., all four of which may or may not be present in a given colony. The reasons are given at length for regarding the color-differentiation as subordinate, and that diversification which includes the element of geographical discontinuity as primary.

On the basis of the full comparisons, it is contended that *var. composita* is directly ancestral to *læva* and to *intermedia*; *exigua* has arisen from the latter only subsequently.

The rôle of the environment in the differentiation of the whole species seems to be negligible so far as causal values are concerned. The production of diverse color-types in one and the same valley could scarcely be attributed to the action of

the identical external influences of that area; the sinistrality of *læva* is not invariable in Maruapoo Valley; the characteristic smaller size of *exigua* is not paralleled by a depauperate condition in any of the accompanying species, *P. hyalina*, *P. clara*, and *P. otaheitana*—the last of which is uniformly sinistral and not dextral. It would seem, then, that the hereditary qualities of the earlier inhabitants or of the first immigrants are the real determining causes of the characters of their descendants, which might vary subsequently, but in no discernible way on account of qualitative effects of the environment.

#### CHAPTER VII.

By far the greater part of the *Partula* population of Tahiti consists of representatives of the complex series *P. otaheitana*, which exists in few or several of its manifold forms in every valley where any larger snails whatsoever were secured. More than 20,000 adults, 6,000 adolescents, together with many thousands of advanced embryonic young, constitute a wealth of material which is peculiarly favorable for an exhaustive analysis; for not only does the species occur in considerable numbers in practically every habitable area of the island, but it is also differentiated with extraordinary clearness into primary, secondary, and even tertiary varieties. Hence the condition of one of its major sections may exceed in complexity that of an entire contrasted species, like *P. clara* or *P. nodosa*. In view of these facts, it is manifestly impossible to give at this juncture more than an outline of the condition of this species and of its evolutionary history.

Taken collectively, the shells of *otaheitana* appear in both modes of coil, with colors ranging from light yellowish-white to deep seal-brown; they vary in the measurable characters of size and shape in ways that may be statistically defined. The pro-*otaheitana* stock was a derivative of a widespread series which became isolated when Tahiti was separated from the other elements of the Society Group, but for the purposes of the present study the extrinsic relations of the species are not important.

Subsequently, the original stock became differentiated into eight primary varieties; *otaheitana* sensu strictu, *amabilis*, *rubescens*, *affinis*, the *sinistrorsa-sinistralis-crassa* group, and *lignaria*. The first of these now exists in Fautaua Valley as the most generalized and most primitive section of the species; its colonial complex of characters comprises virtually all of those which are exhibited by the other more specialized primary varieties, inasmuch as it includes sinistral and direct shells of varying colors and sizes and with banded as well as unbanded patterns. The next division, *amabilis*, inhabits a contiguous section to the north; its representatives differ in successive valleys, but always without relation to geographical or other external circumstances. Eastward and southward of the area occupied by *amabilis* is the territory of two absolutely independent varieties, *rubescens* and *affinis*, which have almost identical geographical limits, yet they stand in the sharpest possible contrast to one another; *rubescens* is large, *always* sinistral, and yellow or reddish in color; *affinis* is predominantly dextral, small in size, and stout in form. They do not interbreed, so far as the evidence goes, even though they must be regarded as derivatives of the same pro-*otaheitana* stock.

The three primary varieties distinguished as *sinistrorsa*, *sinistralis*, and *crassa* are more closely related *inter se*; they inhabit the southern-eastern, southern, and western valleys of the island. Their shells are typically reversed, but dextral representatives occur in certain valleys, sometimes in the majority. The remaining sector of Tahiti, on the northwest, is occupied by *lignaria*, which in certain respects has paralleled *affinis* in its differentiation from the *pro-otaheitana* stock.

Each of the main sections of *otaheitana* is further differentiated to some degree, which in some cases necessitates the establishment of tertiary taxonomic divisions, as in *affinis erythræa* and *crassa occidentalis*. Again, the color-differentiation, like that of *P. nodosa*, has proceeded so far in such groups as *affinis*, *sinistrorsa*, and *crassa* as to justify the employment of special terms, orthographically distinguished for the several types, e. g., *apex*, *cestata*, and *phæa* of *P. otaheitana sinistrorsa* and, *P. o. sinistralis*.

Since its origin as such in a given area, a given primary variety has lost ground or rewon other territories of occupation, for the tides of immigration, in some instances at least, seem to have ebbed and flowed precisely as in the cases of *P. clara* and *P. nodosa*.

Mutation is proven in several cases, both in an ancient area and in a recently occupied region; the mutant character can best be proven to be such in the genetic sense in the case of a departure in the mode of spirality.

The attempt has been made in certain instances to analyze the phenomena of heredity in Mendelian terms. In the nature of the case, the difficulties are well-nigh insuperable, and the results can not be more than suggestive, in the absence of actual breeding experiments. The offspring of a single snail are few in number, the other parent is unknown, the dominant member of a contrasted pair of characters is also unknown, while the proportionate numbers of DD, DR, and RR snails are not to be ascertained by a simple inspection of the adult population. Nevertheless a method has been devised which gives some insight into the mode of inheritance of contrasted qualities, and which also makes it possible to designate one of a pair as a dominant to its alternative. To specify, the red color seems to be a dominant in relation to yellow in *P. otaheitana rubescens* and in *P. otaheitana crassa occidentalis*; the banded pattern seems to be dominant in relation to the absence of bands in *P. otaheitana affinis* and *P. otaheitana sinistrorsa*. These conclusions are in accord with Lang's experimental results on *Helix*.

The congenital factors of variation seem to be paramount in comparison with the "environmental" influences which affect the characters under consideration. Condensing the discussion to its briefest form, the conclusion is based upon certain negative and positive evidences. In the first place no differences in the environmental factors can be discovered that would account for the production of diverse but related *primary varieties* in different regions, or for the origin of a *secondary* form of a primary variety in one valley, while in the areas on either side the novel type does not appear. In the second place, the positive observations show that sometimes species X in the case of two neighboring valleys is the same, while species Y may or may not be the same. It is merely an appeal to ignorance to

contend that, because two distinguishable types occur in neighboring localities, there must be environmental factors for the observed differences; but even this argument breaks down when individuals of a mutant group, like dextral *sinistrorsa*, appear in a valley along with their unchanged relatives. In a word, the rôle of the environment is to set the limits to the habitable areas or to bring about the elimination of individuals whose qualities are otherwise determined—that is, by congenital factors.

## CHAPTER VIII.

For the sake of completeness, a description is given of the species *P. producta* Pease, which is the complete antithesis of *otaheitana* both in its terrestrial habit and in its confinement to a limited area in the southeastern district of Mataiea. In general form, and to some degree also in its coloration, *producta* resembles the other species named, but in the details of both groups of characters it is distinct.

Here there is no opportunity for a study of distribution. The distinctive features of *producta* and its intrinsic variation are of some interest, especially in connection with a wider treatment of the terrestrial species of the genus, which will take into account the forms with similar habits that exist in other islands like Raiatea. For the present this species stands out on account of its contrast with its associates on the island of Tahiti.



## LIST OF PLATES.

	PAGE
PLATE 1. Chart of Oceania. The groups of islands with underlined names are known to be inhabited by species of the genus <i>Partula</i> .....	13
2. The island of Moorea, drawn from charts and photographs. The greatest width near the northern (upper) border is approximately 10 geographical miles.....	14
3. The double island of Huahine, drawn from charts and photographs. The distance from the northern to the southern extremes of the two land-masses taken together (vertical distance) is about 8 geographical miles.....	16
4. The sister islands of Raiatea (lower) and Tahaa (upper)—a photograph of a topographical model constructed on the basis of charts, photographs, and observations. The length of Raiatea in a north-and-south (vertical) direction is 11.5 geographical miles, while the similar diameter of Tahaa is a little less than 6.5 geographical miles.....	18
5 A. The town of Papeete and adjacent valleys. Fautaua Valley is on the right, and its main fork is marked by the summit of the Pic de Française (see Plate 7 B). Hamuta Valley is in the exact center, over the spire of the Cathedral. Pirai Valley runs below and parallel to the great ridge in the distance. Mount Aorai is covered by clouds.....	20
5 B. The alternating ridges and valleys looking toward Mount Aorai from Mount Tahara at the extreme northern point of Tahiti near Point Venus.....	20
6 A. The southwestern portions of Taiarapu, from the shore of Papeari District.....	22
6 B. Looking inland into Temarua Valley (center) and Papeiti Valley (at the right) from the open land near the coast. The thickets of guava and associated bushes in the foreground are characteristic of the drier peripheral shelf and of the lower levels of the valleys.....	22
7 A. The mouth of Faaripoo Valley, in the northern sector of Tahiti nui, showing the character of the country in the drier regions.....	24
7 B. Pic de Française and vegetation, at the main fork of Fautaua Valley, 4 geographical miles from the coast.....	24
8. Dense vegetation of interior areas of the valleys habitable for <i>Partula</i> .....	26
9. Zenith view of topographical model of Tahiti, constructed on the basis of charts, photographs, and observations. The greatest length of the land-mass as modeled (NW. to SE.) is about 44 inches. The vertical scale is twice that of the horizontal.....	28
10. Outline chart of Tahiti and key to Plate 9. The principal topographical data are indicated in black (names of valleys, mountain ridges, and mountain peaks). The names and boundaries of the geographical or administrative districts are given in red.....	28
11. Northern aspect of topographical model of Tahiti, with outline key.....	32
12. Western aspect of topographical model of Tahiti, with outline key.....	34
13. Southern aspect of topographical model of Tahiti, with outline key.....	36
14. Eastern aspect of topographical model of Tahiti, with outline key.....	38
15 A. The western end of Papeete, and Tipaerui Valley. The high ridge in profile forms the main boundary between the northern and western sectors. The dry sector to the east (left) of Tipaerui is free from <i>Partula</i> .....	48
15 B. Papehue Valley, an element of the third order of size, looking inland from near its mouth.....	48
16 A. The region of Otuna, Opiriroa, and Tearatapu Valleys (from left to right) showing the thicker vegetation of the lower levels in the wetter southern quadrant.....	50
16 B. Mangaia, one of the Cook or Hervey Islands—an uplifted atoll.....	50
17 A. Region about coastward portions of Temarua Valley (in the distance), Papeiti Valley (middle distance), and mouth of Teohu Valley (foreground at the right).....	68
17 B. Vairaharaha Valley (on the left) and Vahiria Valley (on the right), looking inland from near their confluent mouths.....	68
18 A. Vegetation of a typical locality for <i>Partula filosa</i> , about 3 miles up Pirai Valley.	82
18 B. Inner part of Pirai Valley, and its vegetation, from a point about 100 feet above level of the stream. Beyond this place very few <i>Partula</i> are to be found.....	82
19. The lower portions of Punaruu Valley looking inland from a height near the shore.	88

PLATE 20.

All shells 1.5 times natural size.

Figs. 1-10. *P. hyalina* Brod., from Tahiti.

Fig. 1. Shortest specimen, Tautira Valley.

Fig. 2. Broadest shell, Otuna Valley.

Fig. 3. Longest shell, Paraura Valley.

Fig. 4. Narrowest shell, Tipaerui Valley.

Figs. 5, 6. Average shells, Fautaua Valley.

Fig. 7. Thin type, Haavini Valley.

Fig. 8. Broken and repaired shell, Papenoo Valley.

Fig. 9. Average shell, showing obliquity of the lip in profile view.

Fig. 10. Adolescent, Pirai Valley.

Figs. 11, 12. *P. hyalina* Brod., from Moki, Cook Islands.

Fig. 13. *P. hyalina* Brod., from Mangaia, Cook Islands.

Figs. 14-17. *P. clara parva* Cr., Punaruu Valley.

Fig. 18. *P. clara parva* Cr., Maruapoo Valley.

Figs. 19-21. *P. clara parva* Cr., Atehi Valley.

Fig. 22. *P. clara parva* Cr., Papehue Valley.

Figs. 23-36. *P. clara incrassa* Cr., Aoua Valley.

Fig. 37. *P. clara minor* Cr., Orofere Valley.

Figs. 38-40. *P. clara minor* Cr., Vaitupa Valley.

Figs. 41-42. *P. clara minor* Cr., Tiamao Valley.









PLATE 21.

All shells 1.5 times natural size.

Fig. 1. *P. clara minor* Cr., Tiamao Valley.

Figs. 2-4. *P. clara angusta* Cr., Tereehia Valley.

Figs. 5-7. *P. clara prima* Cr., Opiriroa Valley.

Figs. 8-11. *P. clara prima* Cr., Teohu Valley.

Fig. 12. *P. clara prima* Cr., Taharua Valley.

Figs. 13, 14. *P. clara prima* Cr., Faarahi Valley.

Figs. 15, 16. *P. clara prima*, Vairaharaha Valley.

Figs. 17-23. *P. clara prima* Cr., Vaihiria Valley.

Figs. 24-29. *P. clara marmorata* Cr., Maara, Apirimaue, Mahaena, Vavii,  
and Haavini Valleys.

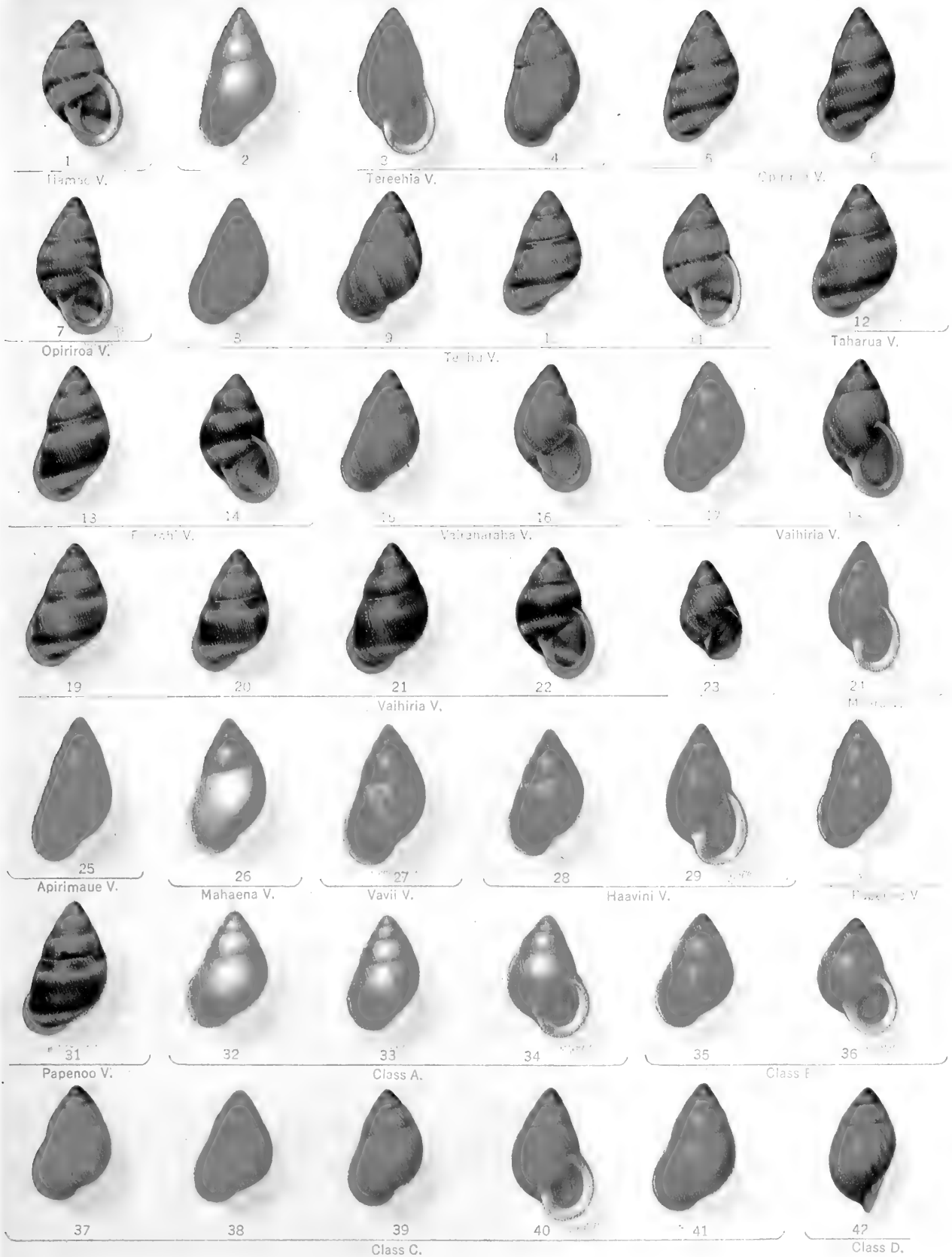
Figs. 30, 31. *P. clara prima* (?), Papenoo Valley.

Figs. 32-34. *P. filosa* Pf., Pirai Valley. Color-class A.

Figs. 35, 36. *P. filosa* Pf., Pirai Valley. Color-class B.

Figs. 37-41. *P. filosa* Pf., Pirai Valley. Color-class C.

Fig. 42. *P. filosa* Pf., Pirai Valley. Color-class D.



*Partula clara* Pease. Figs. 1-31.

*Partula filosa* Pf. Figs. 32-42.





PLATE 22.

All shells 1.5 times natural size.

Figs. 1-4. *P. filosa* Pf., Pirai Valley. Color-class D.

Figs. 5-8. *P. filosa* Pf., Pirai Valley. Color-class E.

Figs. 9-36. *P. nodosa composita* Cr., Taapuna Valley.

Figs 9, 10. Dextral, color-class pallidior Pils. [I].

Figs. 11-21. Dextral, color-class trilineata Pease [II].

Figs. 22-25. Dextral, color-class conrescens Cr. [III].

Figs. 26-30. Dextral, color-class nodosa Pf. [IV].

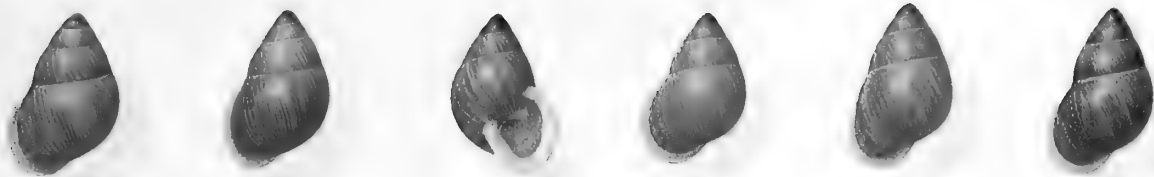
Fig. 31. Sinistral, color-class pallidior Pils. [I].

Figs. 32, 33. Sinistral, color-class trilineata Pease [II].

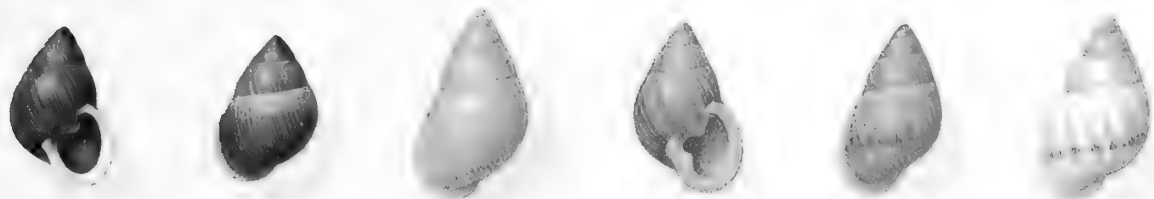
Figs. 34, 35. Sinistral, color-class nodosa Pf. [IV].

Fig. 36. Sinistral, adolescent.

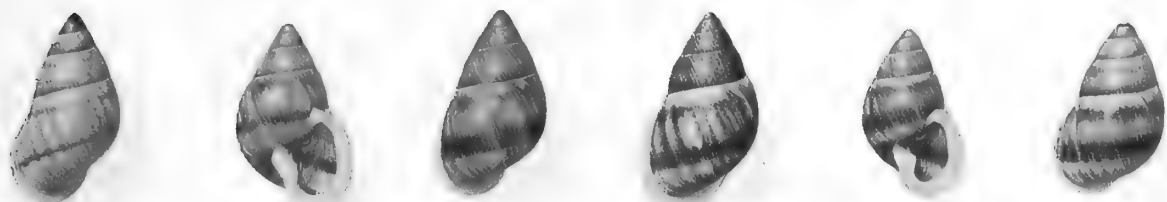




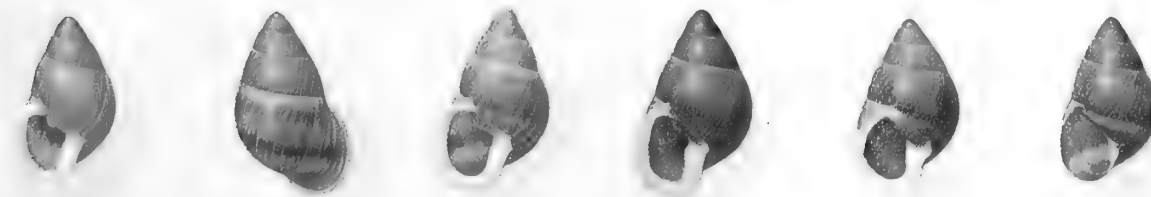
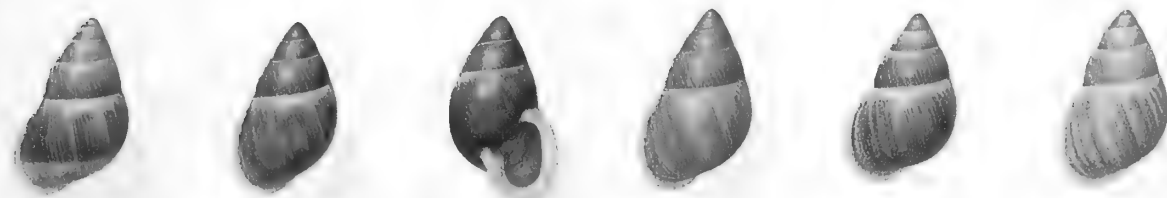
Class D.



Class E.



Taapuna V.



Taapuna V.





PLATE 23.

All shells 1.5 times natural size.

Figs. 1-13. *P. nodosa composita* Cr., Punaruu Valley.

Figs. 1-4. Color-class pallidior Pils.

Figs. 5-11. Color-class trilineata Pease.

Fig. 12. Color-class conrescens Cr.

Fig. 13. Color-class nodosa Pf.

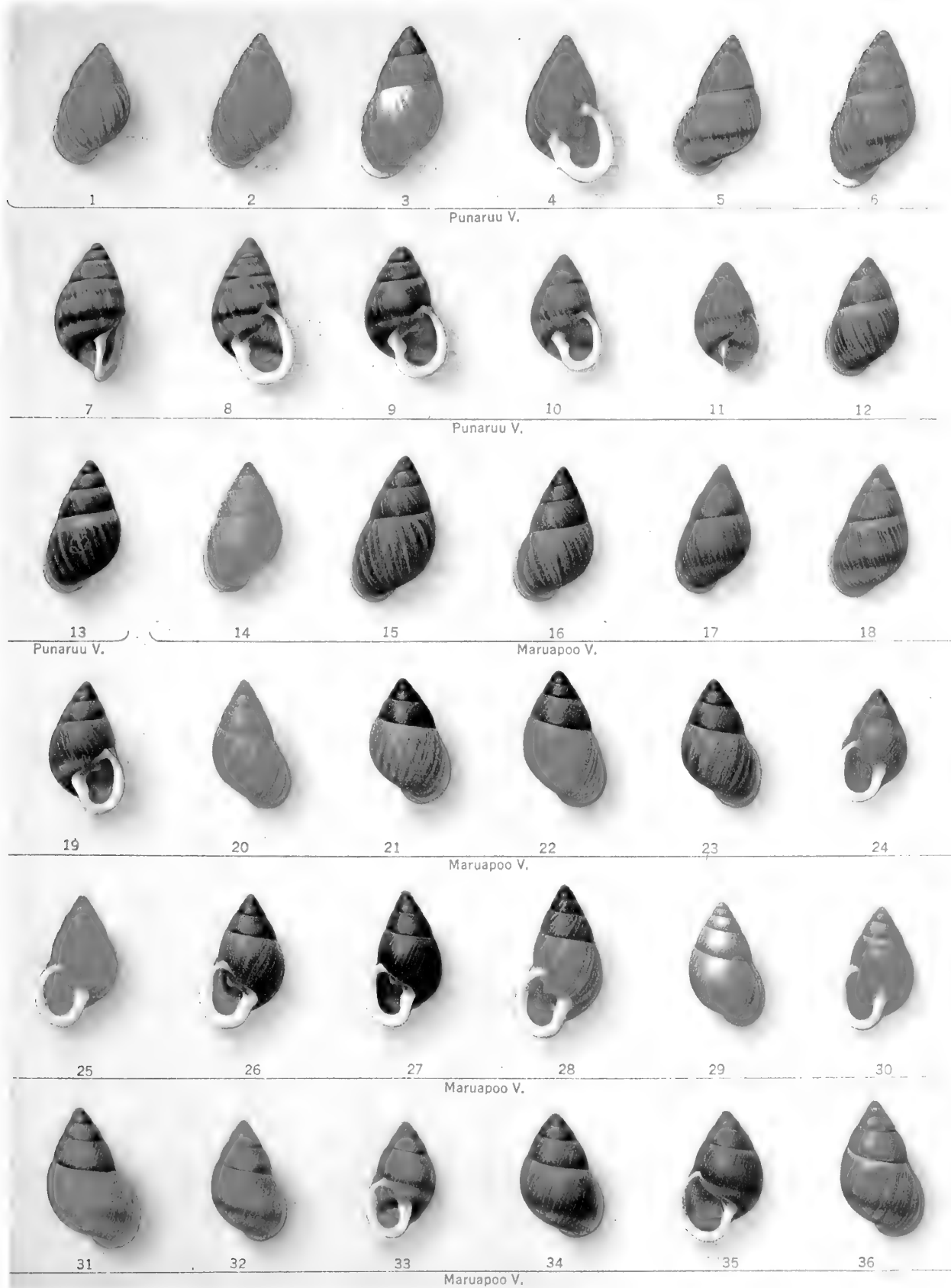
Figs. 14-36. *P. nodosa laeva* Pils., Maruapoo Valley.

Figs. 14-16. Dextral, unbanded.

Figs. 17-19. Dextral, banded.

Figs. 20-28. Sinistral, unbanded.

Figs. 29-36. Sinistral, banded.



*Partula nodosa* Pf. Figs. 1-36.



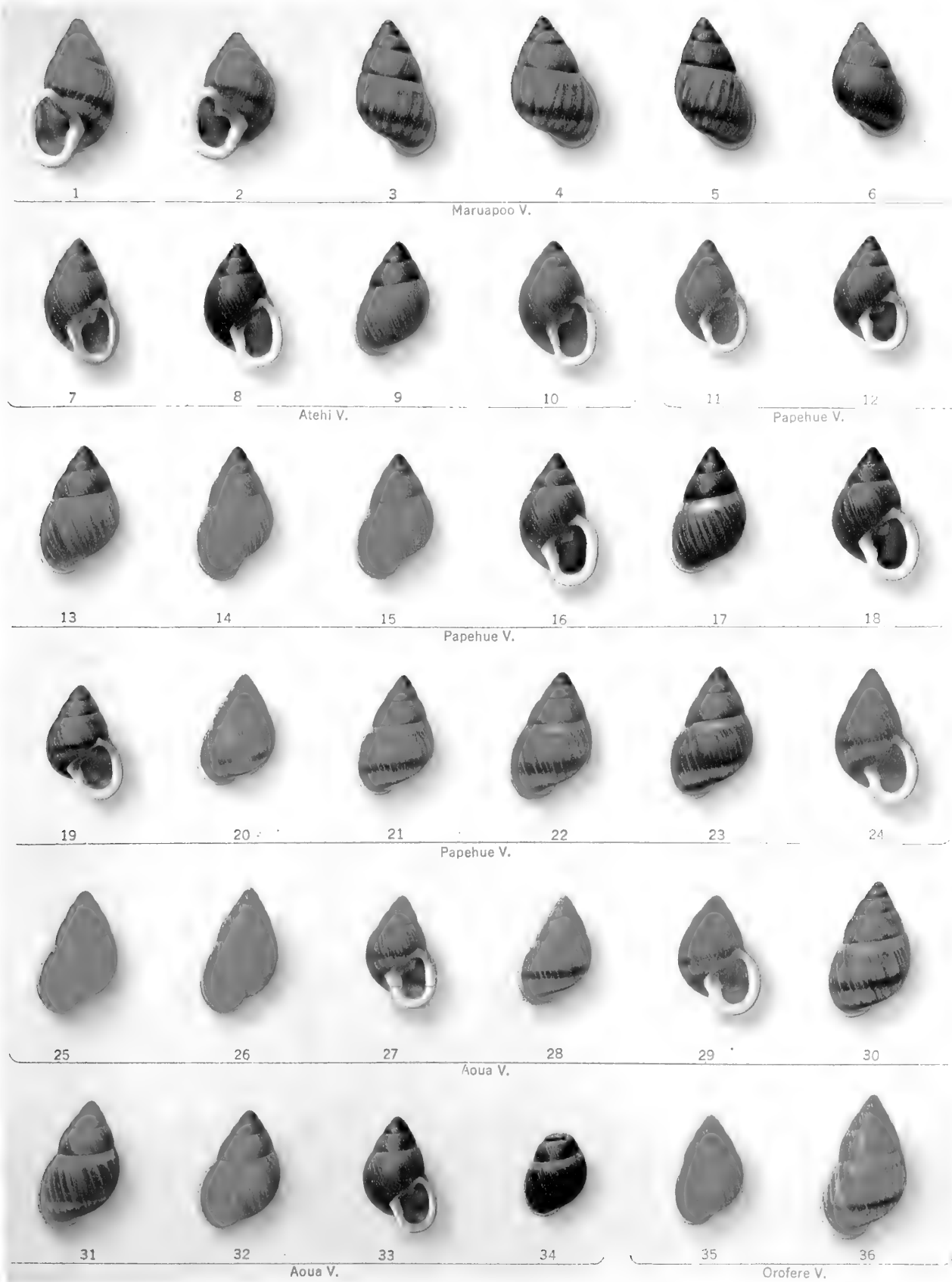


PLATE 24.

All shells 1.5 times natural size.

- Figs. 1-6. *P. nodosa læva* Pils., Maruapoo Valley. Sinistral, banded.  
Figs. 7-10. *P. nodosa exigua* Cr., Atehi Valley.  
Figs. 11-18. *P. nodosa intermedia* Cr., Papehue Valley. Unbanded.  
Figs. 19-24. *P. nodosa intermedia* Cr., Papehue Valley. Banded.  
Figs. 25, 26. *P. nodosa intermedia* Cr., Aoua Valley. Color-class pallidior.  
Figs. 27-30. *P. nodosa intermedia* Cr., Aoua Valley. Color-class trilineata.  
Fig. 31. *P. nodosa intermedia* Cr., Aoua Valley. Color-class conrescens.  
Figs. 32-34. *P. nodosa intermedia* Cr., Aoua Valley. Color-class nodosa.  
Fig. 35. *P. nodosa intermedia* Cr., Orofere Valley. Unbanded.  
Fig. 36. *P. nodosa intermedia* Cr., Orofere Valley. Banded.





*Partula nodosa* Pf. Figs. 1-36.





PLATE 25.

All shells natural size.

Figs. 1-43. *Partula otaheitana otaheitana* (Cr.), Fautaua Valley.

Figs. 1-4. Sinistral, Class I.

Figs. 5-7. Dextral, Class I.

Figs. 8-13. Sinistral, Class II.

Figs. 14-18. Dextral, Class II.

Figs. 19-24. Sinistral, Class III.

Figs. 25-28. Dextral, Class III.

Figs. 29-33. Sinistral, Class IV.

Figs. 34-37. Dextral, Class IV.

Figs. 38, 39. Sinistral, banded.

Figs. 40-42. Adolescents of various growths.

Fig. 43. Embryonic shell.

Figs. 44-65. *Partula otaheitana amabilis* Pf., Hamuta Valley.

Figs. 44-48. Sinistral, "light" class.

Figs. 49-52. Dextral, "light" class.

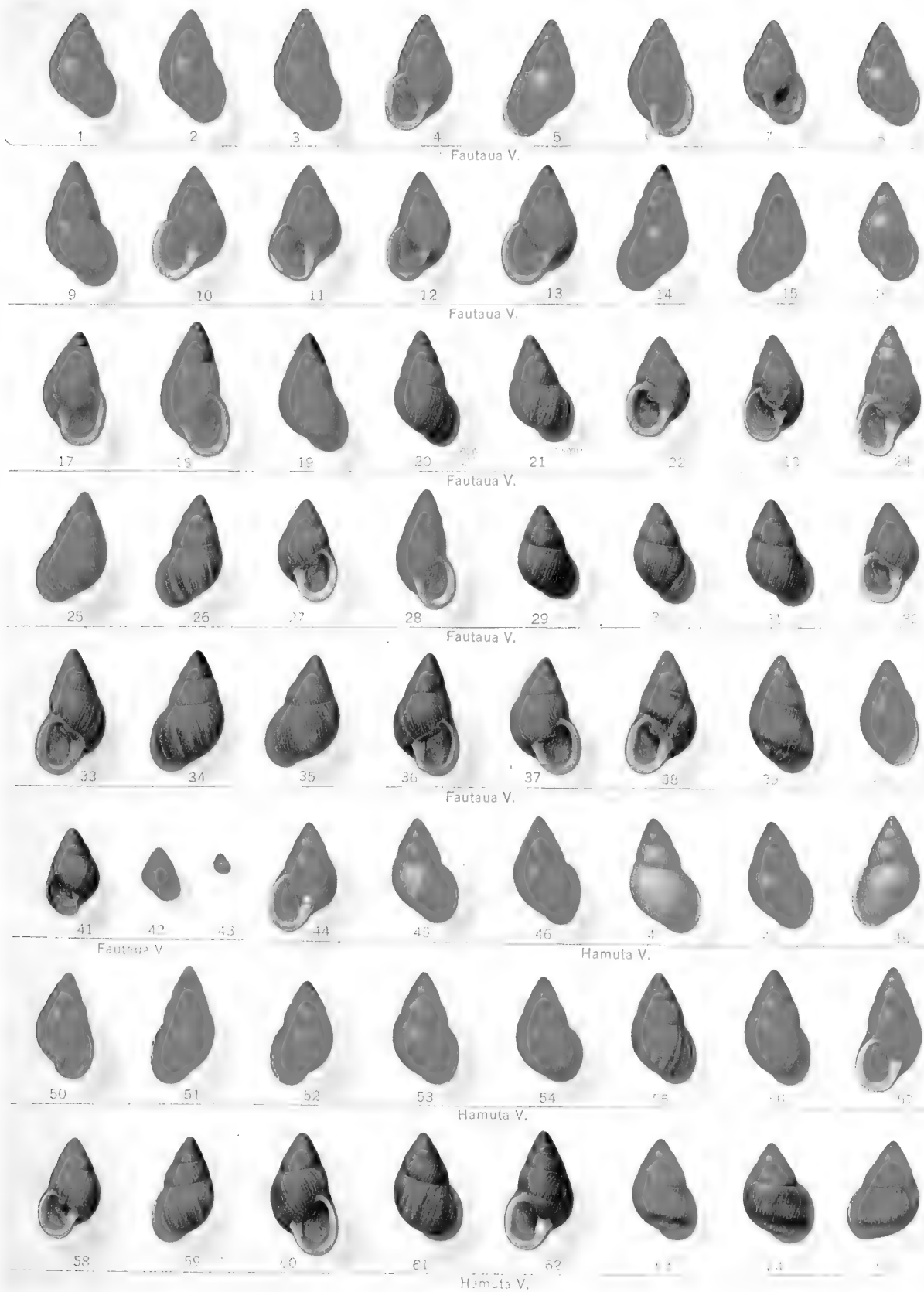
Figs. 53-58. Sinistral, darker classes.

Figs. 59, 60. Dextral, darker types.

Figs. 61, 62. Sinistral, deepest colors.

Figs. 63, 64. Sinistral, banded.

Fig. 65. Dextral, banded.



*Partula otaheitana otaheitana* Cr. Figs. 1-43.

*Partula otaheitana amabilis* Pf. Figs. 44-65.





PLATE 26.

All shells natural size.

Figs. 1-17. *Partula otaheitana amabilis* Pf., Pirai Valley.

Figs. 1-4. Decorticated division (a) of Class I.

Figs. 5-8. Typical division (b) of Class I.

Figs. 9-16. Darker representatives.

Fig. 17. Banded specimen.

Figs. 18-36. *Partula otaheitana amabilis* Pf., Pohaitara Valley.

Figs. 18-22. "Light" class.

Figs. 23-30. "Medium" class.

Figs. 31-36. "Dark" class.

Figs. 37-50. *Partula otaheitana amabilis* Pf., Ururoa Valley.

Figs. 37-39. Sinistral, plain and light.

Figs. 40-43. Sinistral, plain and medium.

Figs. 44-47. Sinistral, plain and dark.

Figs. 48, 49. Sinistral, banded.

Fig. 50. Dextral, plain.

Figs. 51-53. *Partula otaheitana rubescens* Reeve, Tuauru Valley.

Fig. 51. Yellow class.

Figs. 52, 53. Red class.

Figs. 54-63. *Partula otaheitana rubescens* Reeve, Ahonu Valley.

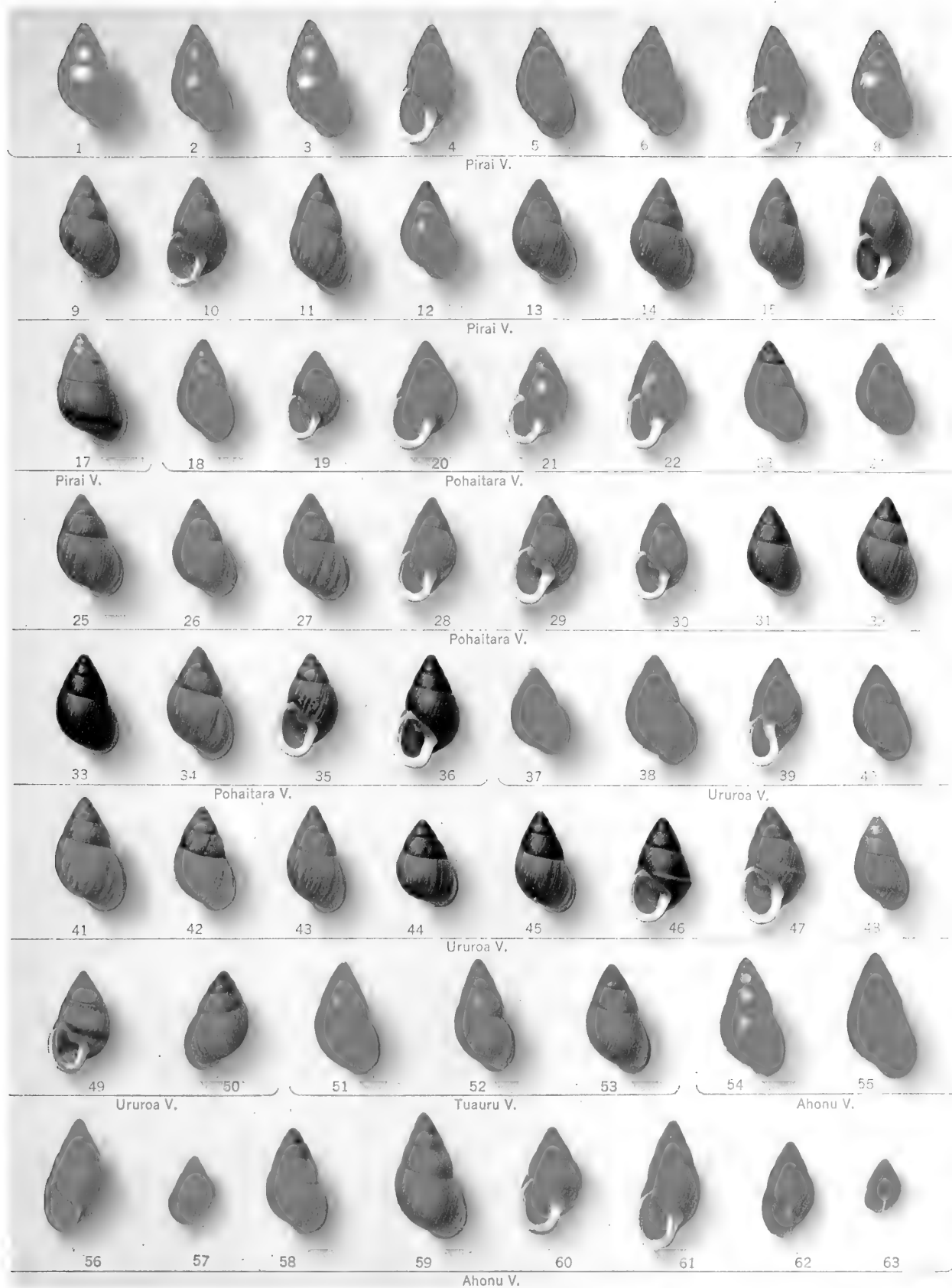
Figs. 54, 55. Adults of yellow class.

Figs. 56, 57. Adolescents of yellow class.

Figs. 58-61. Adults of red class.

Figs. 62, 63. Adolescents of red class.





*Partula otaheitana amabilis* Pf. Figs. 1-50.

*Partula otaheitana rubescens* Reeve. Figs. 51-63.

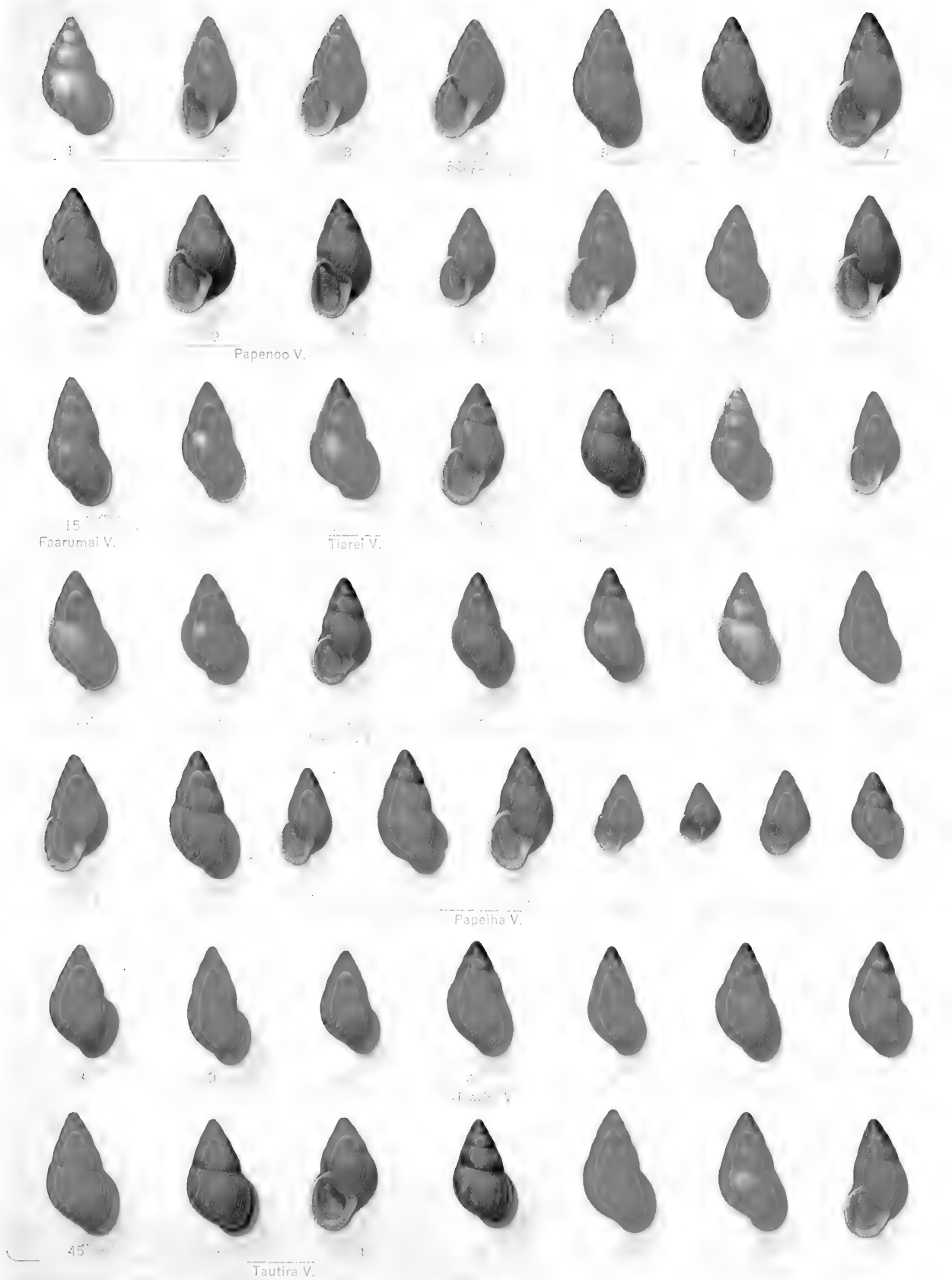




## PLATE 27.

All shells natural size.

- Figs. 1-11. *Partula otaheitana rubescens* Reeve, Papenoo Valley.  
Figs. 1-4. Yellow class; fig. 1, much decorticated specimen.  
Figs. 5-10. Red class, normal.  
Fig. 11. Red class, diminutive specimen.
- Figs. 12-15. *Partula otaheitana rubescens* Reeve, Faarumai Valley.  
Fig. 12. Yellow class.  
Figs. 13-15. Red class.
- Figs. 16-18. *Partula otaheitana rubescens* Reeve, Tiarei Valley.  
Figs. 16, 17. Yellow class.  
Fig. 18. Red class.
- Fig. 19. *Partula otaheitana rubescens* Reeve, Mahaena Valley.
- Figs. 20-26. *Partula otaheitana rubescens* Reeve, Paraura Valley.  
Figs. 20-23. Yellow class.  
Figs. 24-26. Red class.
- Figs. 27-37. *Partula otaheitana rubescens* Reeve, Papeiha Valley.  
Fig. 27. Decorticated yellow specimen.  
Figs. 28, 29. Typical yellow class.  
Figs. 30, 31. Red class, the latter a diminutive mutant.  
Figs. 32, 33. Particolored class.  
Fig. 34. Adolescent, yellow class.  
Fig. 35. Adolescent, red class.  
Figs. 36, 37. Adolescents, particolored class.
- Figs. 38-44. *Partula otaheitana rubescens* Reeve, Haavini Valley.  
Figs. 38, 39. Yellow class.  
Figs. 40-42. Yellow, with tinted apex.  
Figs. 43, 44. Red class.
- Figs. 45-48. *Partula otaheitana rubescens* Reeve, Tautira Valley.  
Fig. 45. Yellow class.  
Figs. 46, 47. Reddish-orange subdivision.  
Fig. 48. Typical red class.
- Figs. 49-51. *Partula otaheitana rubescens* Reeve, Aiurua Valley.  
Figs. 49, 50. Yellow class.  
Fig. 51. Red class.



*Partula otaheitana rubescens* Reeve. Figs. 1-51.





PLATE 28.

All shells natural size.

Figs. 1, 2. *Partula otaheitana rubescens* Reeve, Aiurua Valley. Red class.

Figs. 3-22. *Partula otaheitana rubescens* Reeve, Oopu Valley.

Figs. 3, 4. Partly decorticated, yellow class.

Figs. 5-7. Yellow class, with and without deeply tinted apex.

Figs. 8-10. Orange-colored class.

Figs. 11, 12. Partly decorticated, red class.

Figs. 13-17. Red class.

Figs. 18a-18e. Representative embryonic shells.

Figs. 19-22. Representative adolescent shells.

Fig. 23. *Partula otaheitana rubescens* Reeve, Apirimaue Valley.

Figs. 24-42. *Partula otaheitana affinis* Pease, Tuauru Valley.

Figs. 24-27. Dextral, plain, light.

Figs. 28-34. Dextral, plain, dark.

Fig. 35. Sinistral, plain, light.

Fig. 36.

Figs. 37-41. Dextral, banded.

Fig. 42. Unique particolored specimen.

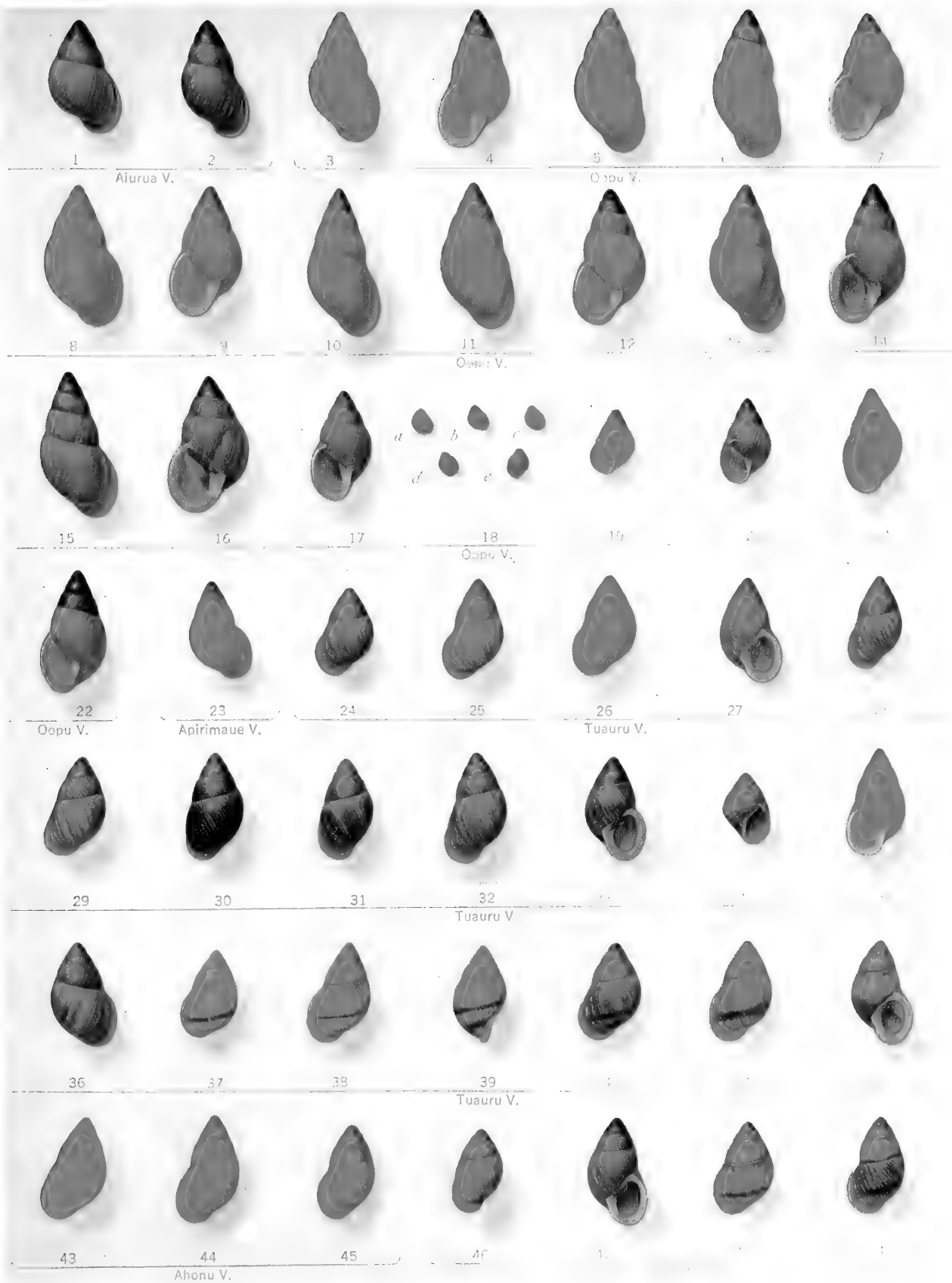
Figs. 43-45. *Partula otaheitana affinis* Pease, Ahonu Valley.

Figs. 46-49. *Partula otaheitana affinis* Pease, Faaripoo Valley.

Figs. 46, 47. Dextral, plain; exceptional forms.

Figs. 48, 49. Dextral, banded.





*Partula otaheitana rubescens* Reeve. Figs. 1-23.

*Partula otaheitana affinis* Pease. Figs. 24-49.





PLATE 29.

All shells natural size.

Figs. 1-5. *Partula otaheitana affinis* Pease, Papenoo Valley.

Figs. 1-3. Dextral, plain.

Figs. 4, 5. Sinistral, plain.

Figs. 6-29. *Partula otaheitana affinis erythræa* Cr., Farapa Valley.

Figs. 6-8. Plain, light class.

Figs. 9-14. Plain, yellow-red class.

Figs. 15-18. Plain, brown class.

Figs. 19-23. Banded, reddish class.

Figs. 24-29. Banded, brown class.

Figs. 30-36. *Partula otaheitana affinis* Pease, Faarumai Valley.

Figs. 30-33. Plain series; shell of fig. 33, a diminutive.

Figs. 34-36. Banded, color-class dubia.

Fig. 37. *Partula otaheitana affinis* Pease, Tiarei Valley. Color-class dubia with partial suffusion.

Figs. 38-41. *Partula otaheitana affinis* Pease, Mahaena Valley.

Figs. 38, 39. Dextral, color-class dubia.

Fig. 40. Sinistral, plain.

Fig. 41. Sinistral, color-class dubia.

Figs. 42-47. *Partula otaheitana affinis* Pease, Vahii Valley.

Figs. 42-44. Plain class.

Figs. 45-47. Banded class; color-class zonata.

Figs. 48-51. *Partula otaheitana affinis* Pease, Paraura Valley.

Figs. 48, 49. Plain class; shell of fig. 49, a giant adolescent.

Figs. 50, 51. Banded, color-class zonata.

Fig. 52. *Partula otaheitana affinis* Pease, Faatautia Valley. Color-class dubia.

Fig. 53. *Partula otaheitana affinis* Pease, Papeiha Valley. Color-class dubia.

Figs. 54-59. *Partula otaheitana affinis* Pease, Tehoro Valley.

Figs. 54-56. Plain class, examples with more or less red color.

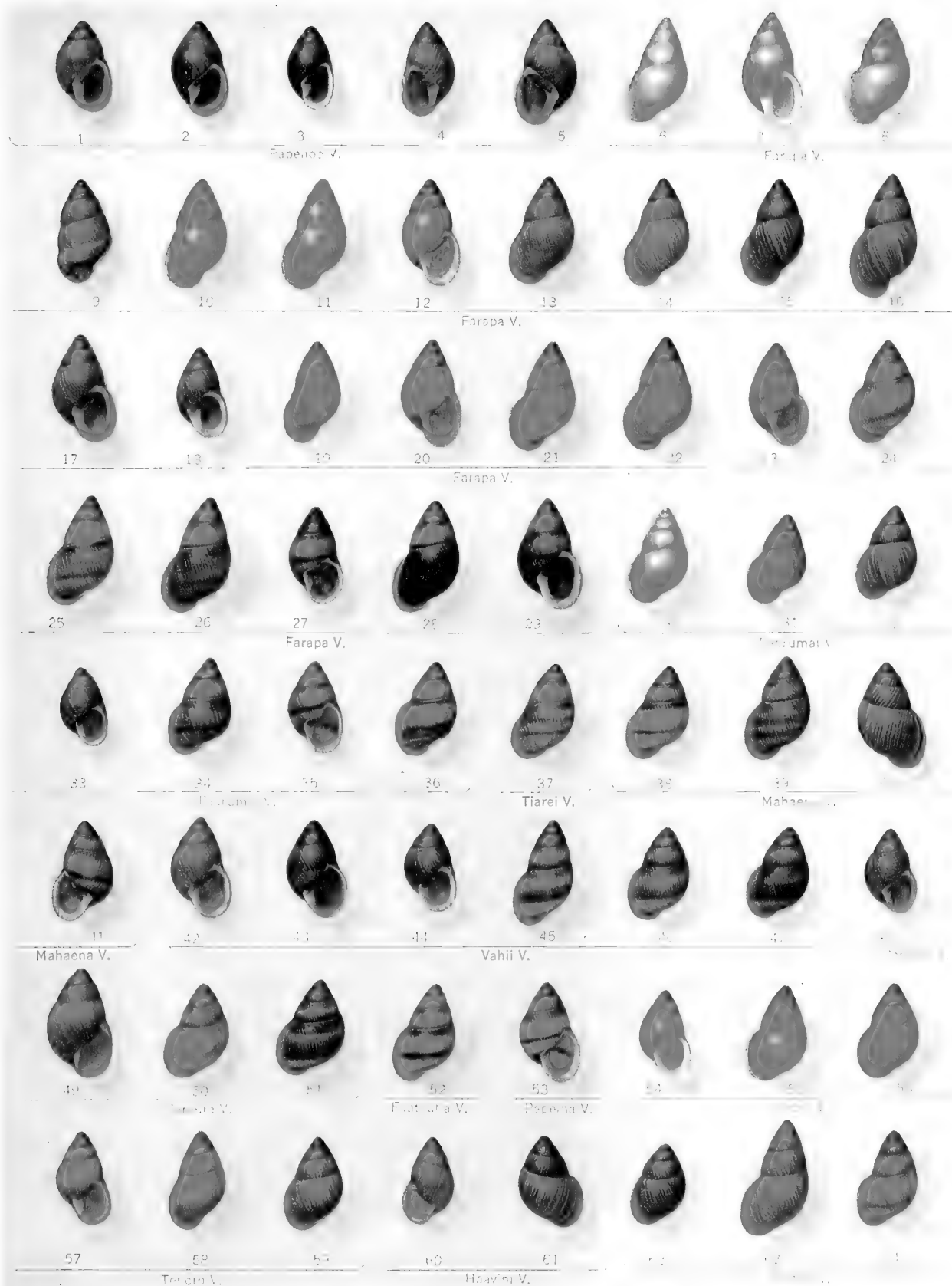
Figs. 57-59. Bicolored class, color-class anomala.

Figs. 60, 61. *Partula otaheitana affinis* Pease, Haavini Valley. Sinistral, plain.

Figs. 62-64. *Partula otaheitana affinis* Pease, Tautira Valley.

Figs. 62, 63. Plain shells, unusual types.

Fig. 64. Banded, color-class dubia.



*Partula otaheitana* affinis Pease. Figs. 1-64.





PLATE 30.

All shells natural size.

Figs. 1, 2. *Partula otaheitana affinis* Pease, Vaiau Valley. Types with reddish admixture.

Figs. 3-7. *Partula otaheitana affinis* Pease, Vaipoe Valley.

Fig. 3. Unusual form, plain.

Figs. 4-7. Banded, color-class *zonata*.

Fig. 8. *Partula otaheitana affinis* Pease, Oopu Valley. Color-class *zonata*.

Fig. 9. *Partula otaheitana affinis* Pease, Apirimaue Valley.

Figs. 10-18. *Partula otaheitana sinistrorsa* Pease, Vaiaaia Valley.

Figs. 10-12. Color-class apex.

Figs. 13-16. Color-class *cestata*.

Figs. 17, 18. Color-class *phæa*.

Figs. 19-23. *Partula otaheitana sinistrorsa* Pease, Aiavaro Valley.

Figs. 19-21. Color-class apex, unusual forms.

Fig. 22, 23. Color-class *cestata*, unusual forms.

Figs. 24-26. *Partula otaheitana sinistrorsa* Pease, Vavii Valley. Color-class *cestata*, subordinate types.

Figs. 27-35. *Partula otaheitana sinistrorsa* Pease, Vaipoe Valley.

Figs. 27, 28. Color-class apex.

Figs. 29-35. Color-class *cestata*.

Figs. 36-49. *Partula otaheitana sinistrorsa* Pease, Titaviri Valley.

Figs. 36-38. Sinistral, color-class apex.

Fig. 39. Dextral adolescent, color-class apex.

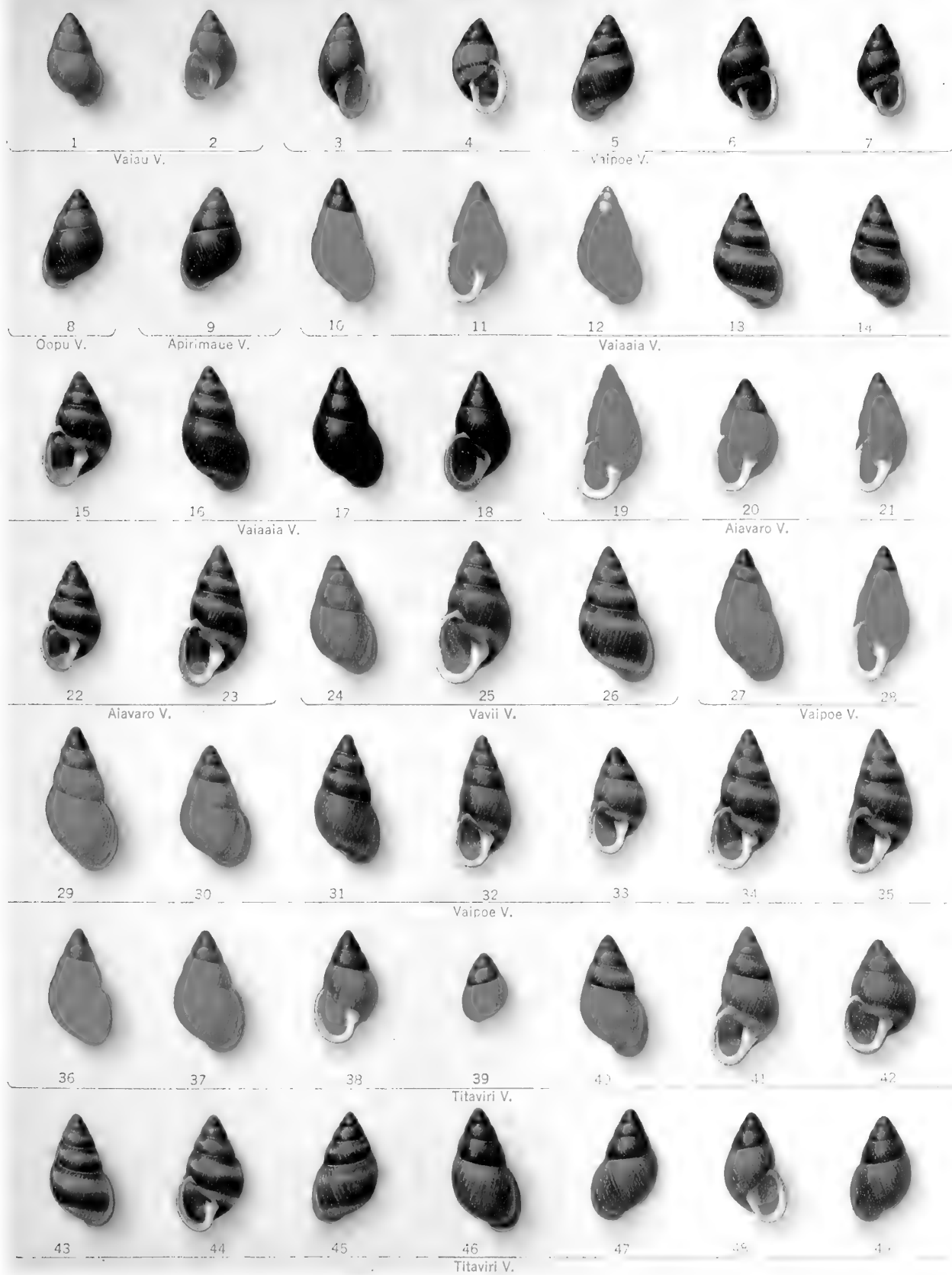
Figs. 40-44. Sinistral, color-class *cestata*.

Fig. 45. Dextral, color-class *cestata*.

Fig. 46. Sinistral, color-class *phæa*.

Figs. 47-49. Dextral, color-class *phæa*.





*Partula otaheitana affinis* Pease. Figs. 1-9.

*Partula otaheitana sinistrorsa* Pease. Figs. 10-49.





PLATE 31.

All shells natural size.

Figs. 1-20. *Partula otaheitana sinistrorsa* Pease, Tenaire Valley.

Figs. 1, 2. Sinistral, color-class apex.

Figs. 3-7. Sinistral, color-class cestata.

Figs. 8-10. Sinistral, color-class phæa; fig. 10, unusually small shell.

Figs. 11-13. Dextral, color-class apex.

Figs. 14-16. Dextral, color-class cestata.

Figs. 17-19. Dextral, color-class phæa,

Fig. 20. Embryos. (a) sinistral cestata from sinistral apex.

(b) dextral apex from dextral phæa.

(c) (d) dextral phæa from dextral phæa.

(e) (f) dextral cestata from dextral cestata.

Figs. 21-28. *Partula otaheitana sinistrorsa* Pease, Vaihiria Valley.

Figs. 21, 22. phæa solida color-type.

Figs. 23, 24. phæa striata color-type.

Figs. 25-28. cestata color-type.

Figs. 29-40. *Partula otaheitana sinistrorsa* Pease, Faarahi Valley.

Figs. 29-34. Sinistral, phæa class.

Figs. 35-38. Sinistral, cestata class.

Fig. 39. Dextral, phæa class.

Fig. 40. Dextral, cestata class.

Figs. 41-51. *Partula otaheitana sinistrorsa* Pease, Moaroa Valley.

Figs. 41-47. phæa class, fig. 47, giant adolescent.

Figs. 48-51. cestata class.

Figs. 52-56. *Partula otaheitana sinistrorsa* Pease, Taharua Valley.

Figs. 52, 53. Sinistral, phæa class. Pallid types simulating apex.

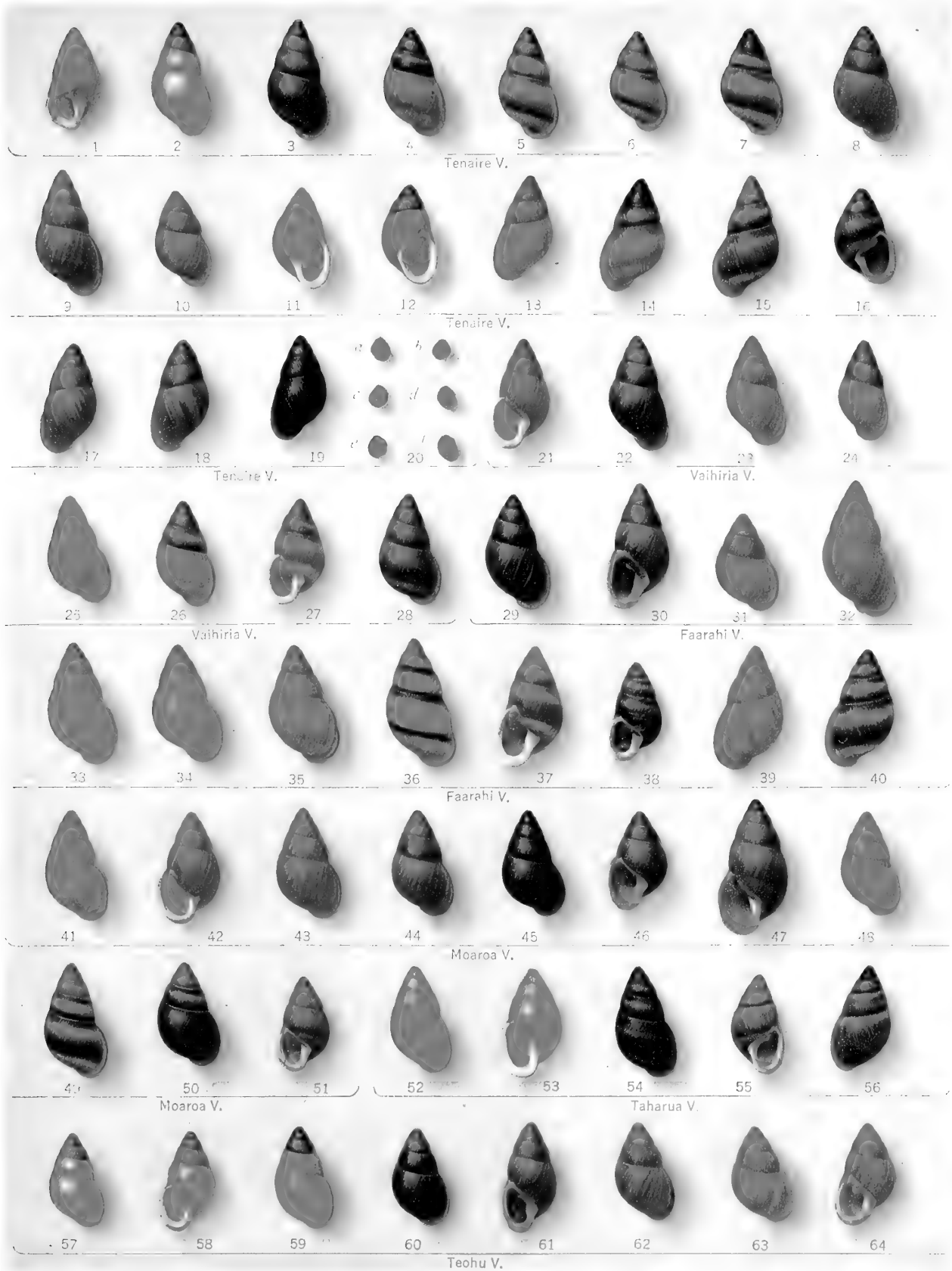
Fig. 54. Sinistral, cestata class, unusually dark.

Figs. 55, 56. Dextral, cestata class.

Figs. 57-64. *Partula otaheitana sinistralis* Pease, Teohu Valley.

Figs. 57-59. apex class.

Figs. 60-64. phæa class.



*Partula otaheitana sinistrorsa* Pease. Figs. 1-56.

*Partula otaheitana sinistralis* Pease. Figs. 57-64.





PLATE 32.

All shells natural size.

Figs. 1-8. *Partula otaheitana sinistralis* Pease, Teohu Valley. cestata class, varieties.

Figs. 9-15. *Partula otaheitana sinistralis* Pease, Papeiti Valley.

Figs. 9-11. phæa striata subclass.

Figs. 12, 13. phæa confluens subclass.

Figs. 14, 15. cestata class.

Figs. 16-22. *Partula otaheitana sinistralis* Pease, Temarua Valley.

Figs. 16-19. Sinistral, phæa class.

Fig. 20. Sinistral, cestata class.

Figs. 21, 22. Dextral, cestata class.

Figs. 23-31. *Partula otaheitana sinistralis* Pease, Opiriroa Valley.

Figs. 23, 24. phæa class.

Figs. 25, 26. Subclass cestata (a).

Figs. 27, 28. Subclass cestata (b).

Figs. 29-31. Subclass cestata (c).

Figs. 32-34. *Partula otaheitana sinistralis* Pease, Otuna Valley. phæa class.

Figs. 35-41. *Partula otaheitana sinistralis* Pease, Maruia Valley.

Figs. 35-38. Sinistral, cestata class.

Fig. 39. Dextral, phæa class.

Figs. 40, 41. Dextral, cestata class.

Figs. 42, 43. *Partula otaheitana sinistralis* Pease, Tereehia Valley. Sinistral and dextral examples of cestata, faintly banded.

Figs. 44-57. *Partula otaheitana sinistralis* Pease, Tiamao Valley.

Figs. 44, 45. Sinistral, subclass cestata (a).

Figs. 46, 47. Sinistral, subclass cestata (b).

Figs. 48, 49. Sinistral, subclass cestata (c).

Figs. 50-52. Dextral, phæa class.

Fig. 53. Dextral, subclass cestata (a).

Figs. 54, 55. Dextral, subclass cestata (b).

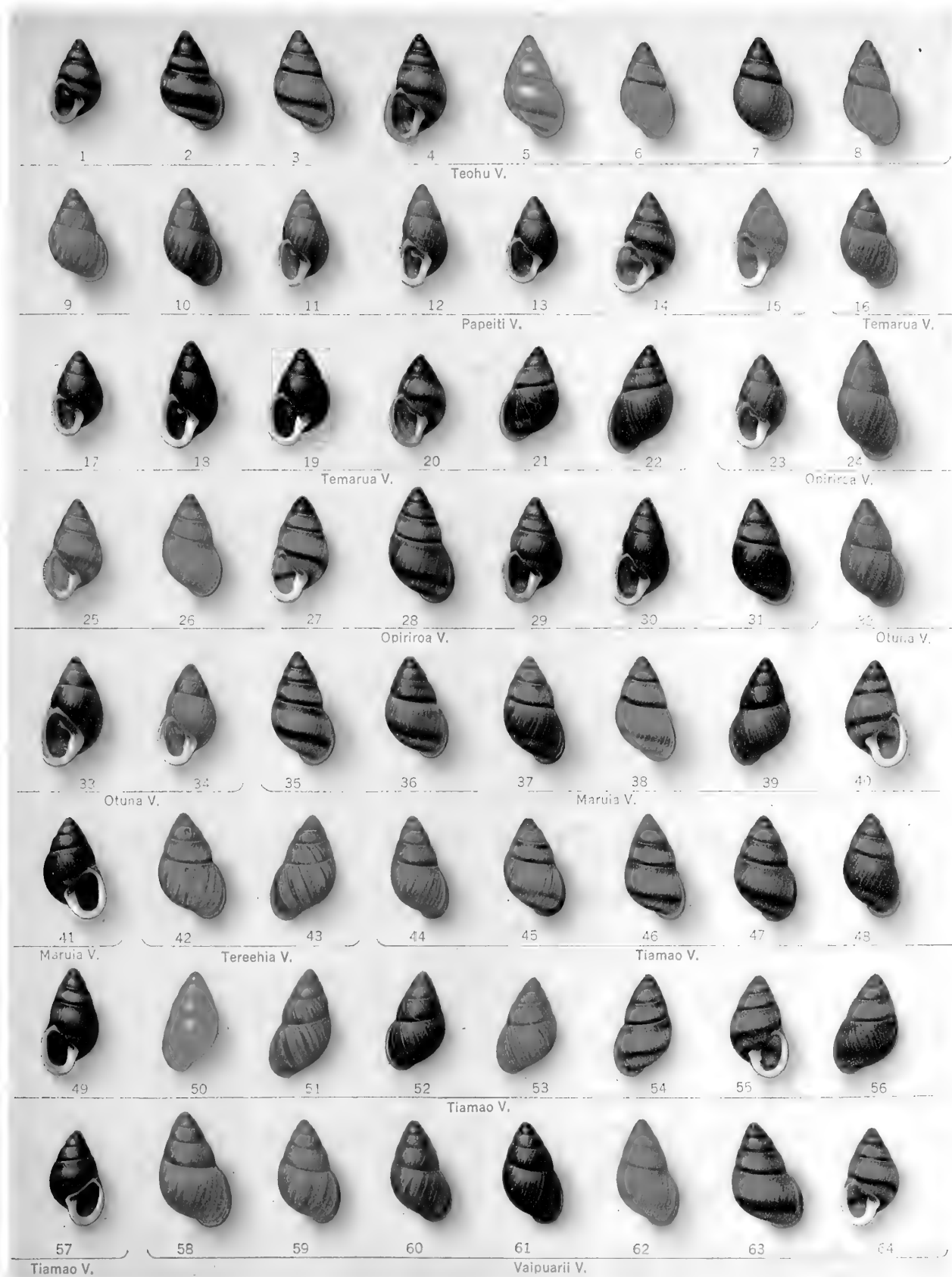
Figs. 56, 57. Dextral, subclass cestata (c).

Figs. 58-64. *Partula otaheitana sinistralis* Pease, Vaipuarī Valley.

Figs. 58-61. phæa class.

Figs. 62-64. cestata class.





*Partula otaheitana sinistralis* Pease. Figs. 1-64.





PLATE 33.

All shells natural size.

Figs. 1-15. *Partula otaheitana crassa* Pease, Vaitupa Valley.

Figs. 1-5. Subclass phæa striata.

Figs. 6-9. Subclass phæa confluens.

Figs. 10-15. Class cestata; fig. 12 adolescent.

Figs. 16-21. *Partula otaheitana crassa* Pease, Atitara Valley.

Figs. 16-19. Subclass phæa striata.

Fig. 20. Class cestata.

Fig. 21. Dextral phæa mutant.

Figs. 22-30. *Partula otaheitana crassa* Pease, Orofere Valley.

Figs. 22-28. Class phæa.

Figs. 29, 30. Class cestata.

Figs. 31-45. *Partula otaheitana crassa occidentalis* Cr., Aoua Valley.

Figs. 31-36. Yellow class.

Figs. 37-42. Red class.

Figs. 43-45. Brown (phæa) class.

Figs. 46-49. *Partula otaheitana crassa occidentalis* Cr., Papehue Valley.

Figs. 46, 47. Yellow class.

Figs. 48, 49. Red class.

Figs. 50-58. *Partula otaheitana crassa* Pease, Atehi Valley.

Figs. 50-53. Class phæa; fig. 50 decorticated shell.

Figs. 54-58. Class cestata.

Figs. 59, 60. *Partula otaheitana crassa* Pease, Maruapoo Valley. phæa class.

Figs. 61-64. *Partula otaheitana crassa* Pease, Punaruu Valley. phæa class.



*Partula otabeitana crassa* Pease. Figs. 1-64.





PLATE 34.

All shells natural size.

Figs. 1, 2. *Partula otaheitana crassa* Pease, Punaruu Valley. Banded class.

Figs. 3-13. *Partula otaheitana crassa aberrans* Cr., Taapuna Valley.

Figs. 3-5. Plain, light group.

Figs. 6-8. Plain, medium group.

Figs. 9-11. Plain, dark group.

Figs. 12, 13. Banded class.

Figs. 14-56. *Partula otaheitana lignaria* Pease, Tipaerui Valley.

Figs. 14, 15. 1906 series, plain, subclass (a).

Figs. 16-18. 1906 series, plain, subclass (b).

Figs. 19-24. 1906 series, plain, subclass (c); figs. 22-24 unusual forms.

Figs. 25-27. 1906 series, plain, subclass (d).

Figs. 28-30. 1906 series, plain, subclass (e).

Figs. 31-35. 1906 series, banded, light subclass.

Figs. 36, 37. 1906 series, banded, medium subclass.

Figs. 38-40. 1906 series, banded, dark subclass.

Fig. 41. 1906 series, below fork, sinistral, plain.

Figs. 42-46. 1906 series, west fork, dextral, plain.

Figs. 47-50. 1906 series, west fork, sinistral, plain.

Figs. 51, 52. 1906 series, east fork, dextral, plain.

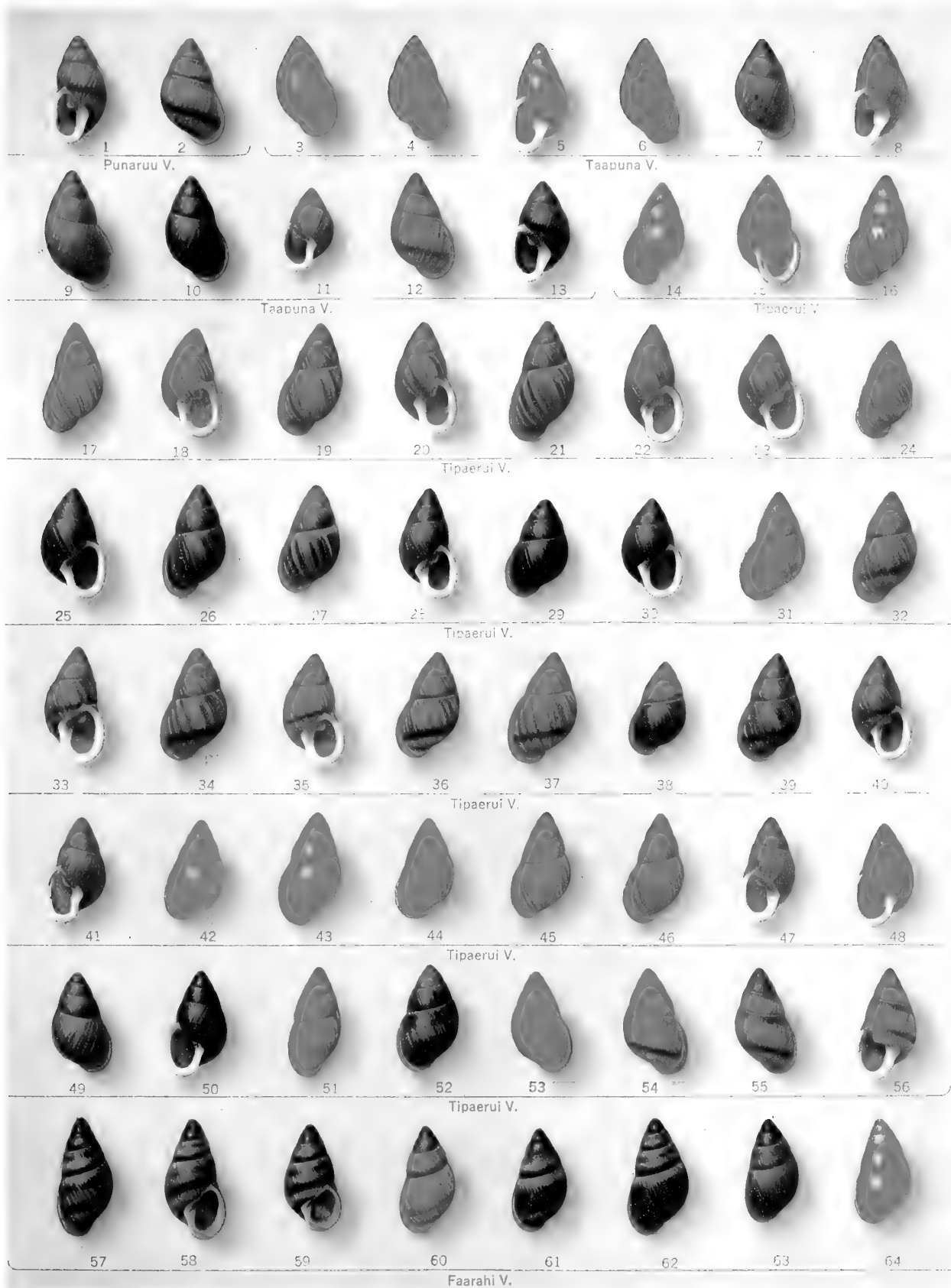
Figs. 53-56. 1906 series, east fork, sinistral, banded.

Figs. 57-64. *Partula producta* Pease, Faarahi Valley.

Figs. 57-63. Banded class.

Fig. 64. Plain, light.





ANCEN & CO. BALTIMORE MD.

*Partula otaheitana crassa* Pease. Figs. 1-13

*Partula otaheitana lignaria* Pease. Figs. 14-56.

*Partula producta* Pease. Figs. 57-64.

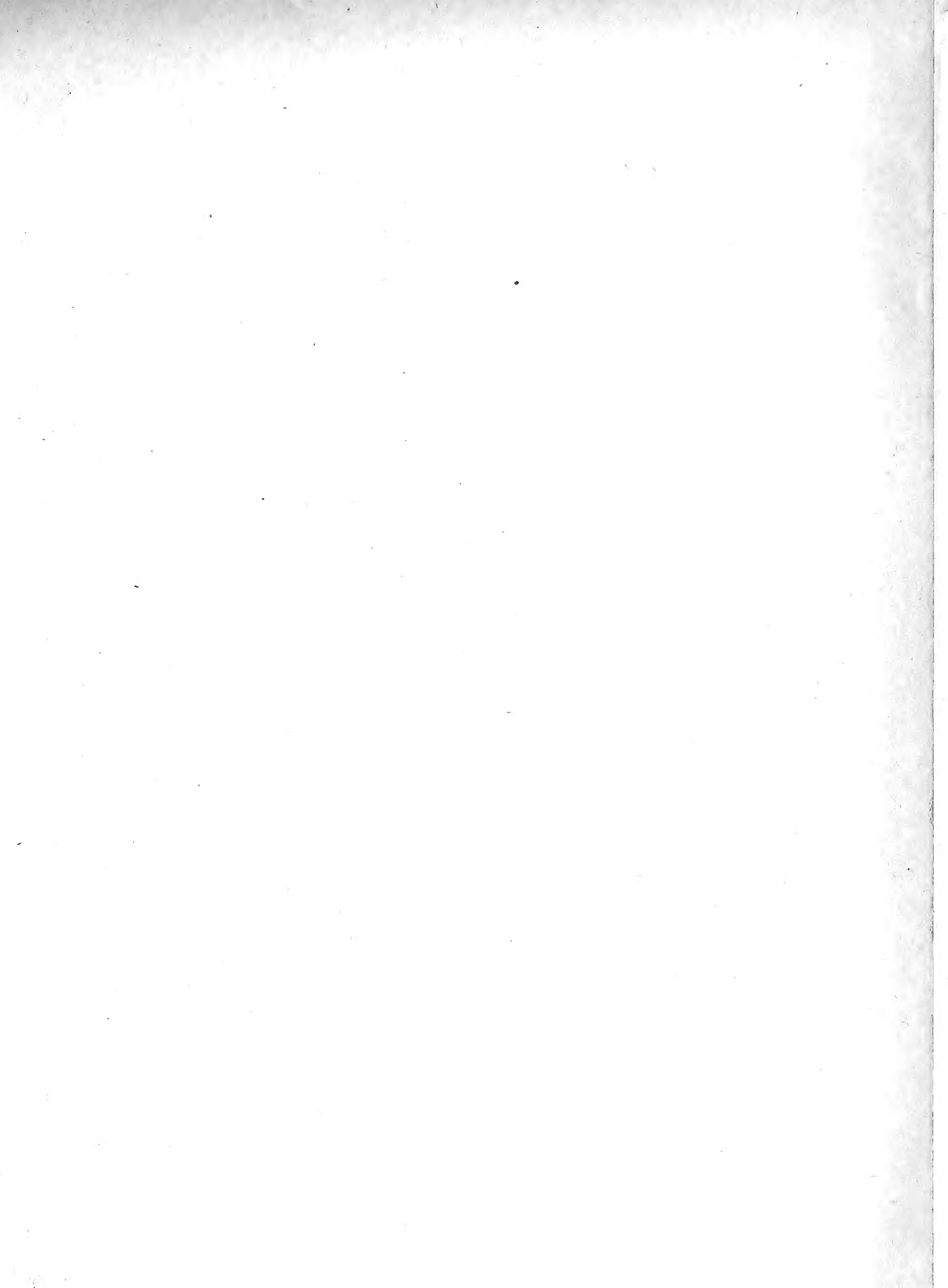








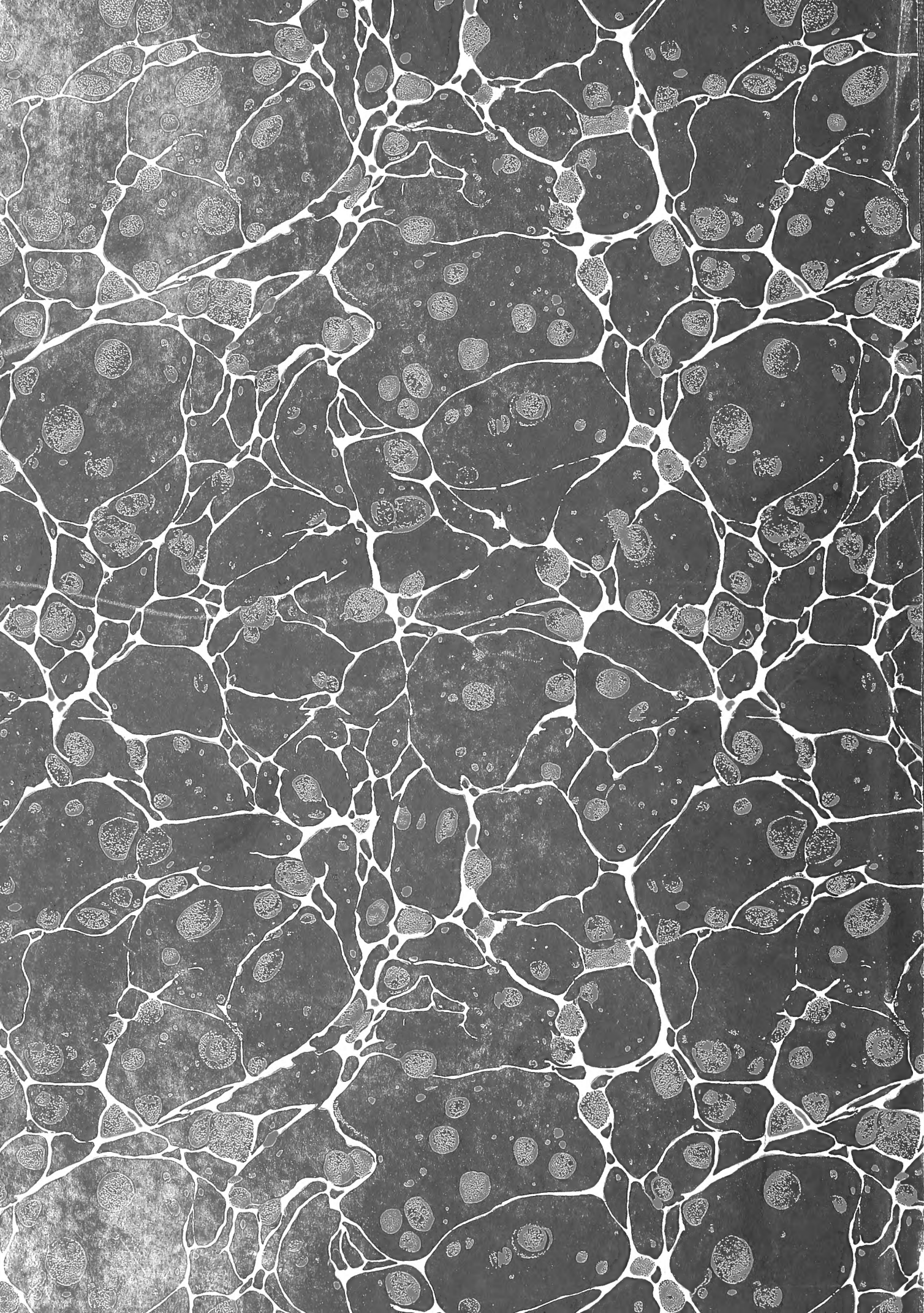












SMITHSONIAN INSTITUTION LIBRARIES  
3 9088 00876 6644